U. S. DEPARTMENT OF AGRICULTURE.
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MISCELLANEOUS PAPERS.

I. THE RELATION OF NICOTINE TO THE BURNING QUALITY OF TOBACCO.
By WIGHTMAN W. GARNER, *Scientific Assistant, Tobacco Investigations.*

II. THE GRANVILLE TOBACCO WILT.
By ERWIN F. SMITH, *Pathologist in Charge of the Laboratory of Plant Pathology.*

III. THE FLORIDA VELVET BEAN AND ITS HISTORY.
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IV. THE IMPORTANCE OF BROAD BREEDING IN CORN.
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V. THE PRESENT STATUS OF THE CHESTNUT-BARK DISEASE.
By HAVEN METCALF, *Pathologist in Charge*, and J. FRANKLIN COLLINS, *Special Agent, Investigations in Forest Pathology.*

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MISCELLANEOUS PAPERS.

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THE RELATION OF NICOTINE TO THE QUALITY OF TOBACCO.

By Wightman W. Garner, *Scientific Assistant, Tobacco Investigations.*

VARIATION IN THE NICOTINE CONTENT OF TOBACCO.

Nicotine has long been recognized as the characteristic alkaloid of tobacco, but its function in the economy of the plant is not understood. It is present in the plant in the earliest stages of growth and is found alike in the roots, stalks, stems, and leaves. As the development and growth of the plant proceed the percentage of nicotine contained in the leaf constantly increases, reaching its maximum at maturity. On the other hand, as is well known, the maximum content of protein nitrogen is found in the young green leaves which are growing rapidly. These facts seem to indicate that nicotine does not enter into the synthesis of the albuminoids from simpler forms of nitrogen, but rather that it is derived from katabolic changes in the albuminoid constituents, and thus continues to accumulate in the tissues so long as these are vitally active.

The amount of nicotine contained in tobacco from different sources is subject to very wide variations, some samples containing less than 1 per cent, while others contain more than 5 per cent. The production of this alkaloid in the plant is influenced by a large number of factors, the relative importance of which has not been determined. No reliable conclusions can be drawn from a study of the nicotine content of tobaccos grown in different parts of the world for the reason that we are always dealing with a complex group of factors and the effect of any single factor can be determined only by experiments so planned and conducted as to exclude, or at least to control, the effects of all others. In a very general way, however, it can be said that very rich heavy soils and excessive quantities of nitrogenous fertilizers, which tend to produce a coarse, rank growth, produce a high percentage of nicotine. This relation is but a rough one and applicable only to sharply contrasted differences in soils and fertilizers. The investigation of this subject carried on by the writer, though as yet incomplete, points unmistakably to the fact that in the case of any given variety of tobacco grown in a particular locality—that is, under approximately the same environment—the percentage of nicotine in different strains is roughly proportional to the albuminoid nitrogen; but when markedly different varieties grown in different localities are compared, this relation does not hold.

From what has been said concerning the production of nicotine and its functions in the economy of the plant it might be inferred that the amount formed is controlled by external conditions of environment and not by heredity, but our experiments along this line with several varieties and strains, as well as with hybrids, have shown conclusively that there is a well-defined varietal influence distinct from external conditions, such as soil, fertilizers, temperature, moisture, and sunlight. As has been stated in a previous publication of this Department,[a] there is every reason to believe that by systematic breeding it is practicable to procure strains of the important types of tobacco characterized by a high or a low nicotine content, provided the external conditions with reference to soils, fertilizers, and cultural methods are properly controlled. Extensive experiments with this object in view are now well under way. This work includes not only a systematic study as regards their nicotine content of large numbers of selections from different types, but also experiments intended to determine the relative influence on the production of nicotine of the various factors which go to make up the environment in which the plant grows. To these should be added the effects of topping and suckering, practices which are now almost universal.

It has already been stated that the maximum content of nicotine in the case of the leaf of the tobacco plant is attained just as the leaf reaches maturity. After this period the leaf begins to lose a part of its nicotine whether the plant is allowed to remain in the field or is harvested. Every tobacco grower is familiar with the sharp, pungent odor so noticeable in the curing shed and in the fermentation room, and this odor is due primarily to the nicotine which is escaping from the tobacco. From the time the tobacco is hung in the curing shed it continues to lose nicotine throughout the curing, fermentation, and aging processes. The writer has found that well fermented samples of cigar tobacco are still slowly losing their nicotine after being kept in tightly stoppered bottles for more than two years. The cause of this continued loss of nicotine will be discussed later.

RELATION OF TOTAL NICOTINE CONTENT TO THE QUALITY OF TOBACCO.

Although nicotine is the active principle of tobacco its production in large quantities is not desirable. On the contrary, the finest grades of tobacco contain only moderate (and even relatively small) amounts of this principle. It has long been recognized that the aroma is not governed by the amount of nicotine in the leaf, but some investigators have suggested that this important quality is due to its decom-

[a] Bureau of Plant Industry Bulletin No. 102, Part VII. "A New Method for the Determination of Nicotine in Tobacco." 1907.

position products formed during the fermentation process. No direct evidence has been furnished in support of this view, and several facts point to the contrary. But even if this view be correct it does not follow that a high nicotine content is desirable, for in the matter of aroma we have to do with quality rather than with quantity.

As regards the so-called "strength" of tobacco, the case is somewhat different. This term is frequently used to designate the degree of physiological reaction of the system to the use of the tobacco in question, and when thus restricted the "strength" of a sample of tobacco depends on the amount of nicotine present. But this term is also frequently applied to the more direct effect of the tobacco or its smoke on the mucous membrane of the throat and nose. For example, when a high-grade Havana cigar is smoked it proves extremely satisfying to the smoker and produces a marked physiological reaction, while the smoke exerts only a remarkably bland effect on the mucous membrane. On the other hand, some of our domestic cigar-filler tobaccos when smoked are not only less satisfying in their narcotic effects, but the smoke has a marked pungency and is irritating and biting to the nose and throat. These tobaccos are almost invariably classed as strong as compared with the Havana, whereas they actually contain less nicotine than the latter. Of course, these same differences may also be noted in different samples of the various domestic types. A long series of comparative tests conducted by the Bureau of Plant Industry has failed to establish any direct relation between the nicotine content and the strength of the various samples of domestic filler tobaccos as judged and classified by a number of habitual smokers.

In any event it seems best to consider the term "strength" as a composite one, made up essentially of two factors. The true physiological action which constitutes the satisfying effects to the consumer so strikingly exemplified in the Havana tobacco is commonly spoken of as "fullness" of the smoke, while the relative freedom from the pungent, biting quality is designated by the term "smoothness." Thus, the Havana cigar tobaccos owe their great popularity among discriminating smokers largely to the marked fullness and smoothness of the smoke, while nearly all of our domestic filler tobaccos possessing sufficient fullness are characterized by a more or less well-defined roughness or harshness. Fullness and smoothness are generally, but not necessarily, opposed qualities of tobacco smoke.

DIFFERENT FORMS OF NICOTINE IN TOBACCO.

It has often been found in attempts to grow cigar-filler tobaccos in this country from Cuban seed and under conditions of soil and climate resembling those of Cuba that although of excellent quality

in other respects the smoke possesses the peculiar pungency or harshness just mentioned. This defect is partially and sometimes efficiently remedied by resweating, followed by a long aging process. In some cases this resort fails and it is necessary to blend the tobacco with some very mild type before it can be used to advantage in the manufacture of cigars. This sharp, biting quality has often been attributed to the presence of an ethereal oil, but such a substance has never been isolated from cured tobacco.

In the course of our experiments with a sample of domestic filler tobacco possessing the above-mentioned objectionable character to a marked degree, it was found that this quality was entirely lost after the tobacco had been extracted with petroleum ether. After evaporating off the petroleum ether from the extract the residue upon warming gave off fumes which were extremely pungent and irritating to the nose and throat. Upon examination these fumes were found to consist essentially of nicotine vapors. The nicotine is readily isolated from the extract by agitating the solution in petroleum ether with water containing sulphuric acid. The aqueous layer containing the nicotine is well washed with petroleum ether and after adding an excess of alkali to free the nicotine from the sulphuric acid is once more extracted with petroleum ether of very low boiling point or with ordinary ethyl ether. After evaporation of the ether from this extract the nicotine is left as a residue in almost pure condition. This residue retains all the pungency of the original extract, while the latter after removal of the nicotine no longer possesses this property.

A large sample of nicotine was purified by converting it into the citrate in aqueous solution and repeatedly extracting this solution with ether. The nicotine was then liberated with an excess of alkali, extracted from the aqueous layer with ether, and the ether solution dried. After evaporating the ether the nicotine was twice distilled in a current of hydrogen. The odor of this product was identical with that obtained by extracting the tobacco with petroleum ether, as already described. Although the peculiar sharpness or pungency of the smoke from tobacco of the kind in question is removed by extracting the tobacco with petroleum ether, and this quality is due to nicotine, all of the nicotine is not by any means removed in this treatment.

Kissling has studied the relative amounts of nicotine salts removed from samples of tobacco from several different sources by extraction with petroleum ether, with ordinary ether, and with alcohol. A certain definite portion of the nicotine, usually much less than half, is readily removed by extraction with petroleum ether, while further treatment with this solvent removes only traces of the remaining nicotine. It is perfectly clear, then, that nicotine is present in

tobacco in at least two forms, one of which is soluble in petroleum ether while the other is practically insoluble.

Tobacco normally contains relatively large quantities of malic and citric acids, from 5 to 10 per cent, a portion of which is in combination with potash or lime and is of great importance in connection with the burning qualities of the leaf. Of these acids the portion above that required for combining with the lime and potash is doubtless largely combined with nicotine.

Nicotine, though quite volatile in the free state, is strongly basic and forms comparatively stable salts with acids which are not readily volatile. The nicotine salts of the difficultly volatile polybasic organic acids, such as malic, succinic, citric, and oxalic acids, are practically insoluble in petroleum ether; and, hence, the nicotine in combination with these acids would not be removed by extraction with this solvent. There seems to be no reason for supposing that freshly cured tobacco contains any of the volatile fatty acids, such as acetic and butyric acids, but it is well known that these acids are formed in the fermentation process from the malic and citric acids, or possibly more directly from succinic acid, which is itself formed by the fermentation of the citric and malic acids. Acetic acid, like nicotine, is easily volatile, and so nicotine acetate is also readily volatile. Moreover, this salt is readily soluble in petroleum ether. Ammonia is likewise a product of the fermentation of tobacco, and the small quantity of acetic acid formed in the fermentation of tobacco and which escapes volatilization is to be found in combination with either ammonia or nicotine.

Practically all tobaccos appear to contain more nicotine than is required for neutralizing all of the stronger organic acids which are not already in combination with mineral or inorganic bases. In other words, it appears that a portion of the nicotine contained in tobacco is present in practically a free state. It possibly does not exist in an absolutely free condition, but rather in loose combination with very weak acids of the order of tannic acid or those derived more directly from the splitting of the chlorophyll constituents. Such unstable salts would act in most respects like the free base. At any rate, the greater portion of the nicotine removed from tobacco by extraction with petroleum ether can be titrated with sulphuric acid directly, the same as if it were in the free state.

EFFECTS OF FERMENTATION AND AGING ON THE DIFFERENT FORMS OF NICOTINE IN TOBACCO.

It has long been known that there is a decided loss of nicotine in the fermentation process, and the amount varies from 10 to 15 per cent in the case of wrapper-leaf tobaccos to as much as a third of the total nicotine content in filler types. Different opinions have been

advanced as to whether these losses are due principally to simple volatilization of the nicotine or to its decomposition. Those who have had experience in the packing house where the fermentation is carried on do not need to be reminded of the sharp, disagreeable, and often nauseating odor emitted from the fermenting bulks, and this characteristic odor is due principally to the volatilization of the nicotine. This volatilization of the nicotine is not confined to the fermentation, but is marked throughout both the air-curing and the flue-curing processes. Now it can be very readily demonstrated that there is practically no volatilization of nicotine when combined with malic or citric acids even at the highest temperatures reached in the fermentation bulks or in the curing barn in the flue-curing process. Of course this statement would not apply to the portion of these salts in which the acid constituents undergo fermentation, forming volatile fatty acids.

Since the nicotine salts of malic and citric acids are insoluble in petroleum ether, it is very instructive to compare the amounts of nicotine removed by extraction with this solvent before and after fermentation. The following table shows the percentage of nicotine soluble in petroleum ether before and after fermentation, as well as the loss of this base in the fermentation process, in the case of a sample of Connecticut shade-grown wrapper-leaf tobacco:

TABLE I.—*Nicotine soluble in petroleum ether in a sample of Connecticut wrapper-leaf tobacco before and after fermentation.*

	Per cent.
Total nicotine before fermentation	3.39
Total nicotine after fermentation	2.89
Loss of nicotine in the fermentation process	0.50
Nicotine soluble in petroleum ether before fermentation	1.60
Nicotine soluble in petroleum ether after fermentation	1.01
Difference	0.59

It will be seen that the total loss of nicotine in fermentation corresponds very closely to the difference between the amounts soluble in petroleum ether before and after the fermentation, and it is highly probable that nearly all of this loss is due to simple volatilization. As is to be expected, the loss of nicotine is greatest in those cases in which the temperatures of the fermenting bulks reach the highest points. This volatilization of nicotine which takes place during the curing, and especially in the fermentation process, continues throughout the subsequent aging of the tobacco, but of course at a diminished rate. It is easy to understand, therefore, the marked improvement brought about by resweating or a long period of aging in the case of those types of tobacco containing excessive quantities of nicotine in an easily volatile form, which imparts a very undesirable sharpness or pungency to the smoke.

In addition to these marked losses of nicotine by simple volatilization, there is a further decrease brought about by a process of oxidation. This latter transformation is a very slow one, and while it plays a part in the production of the brown color of tobacco it is not of importance as regards the total nicotine content. The slow oxidation of the nicotine to thick, brown-colored, tarry substances begins in the curing shed and is a continuous process thereafter, affecting alike the difficultly volatile and the easily volatile forms.

EFFECTS OF ORGANIC ACIDS ON THE NICOTINE CONTENT OF TOBACCO.

It has already been pointed out that, while the true physiological effect produced by the smoke of a given sample of tobacco depends essentially on the total nicotine content, one important factor pertaining to the strength of the tobacco as this term is generally understood—i. e., the sharpness of the smoke—is the amount of the nicotine present which acts as if it were in the free state in that it is readily volatile. Furthermore, it has been shown that this easily volatile form of the nicotine is readily soluble in petroleum ether, while the nicotine which is in combination with malic and citric acids is not soluble. It follows, therefore, that the sharpness shown by the smoke of any tobacco should be removed either by extracting the tobacco with petroleum ether or, equally as well, by adding a sufficient quantity of malic or citric acid to combine with all the nicotine present.

We have made a number of experiments along this line with a sample of domestic filler tobacco which was especially well adapted for this purpose, and the results appear to justify fully the above conclusions. This tobacco was of excellent quality in nearly every respect except that the smoke was extremely sharp and pungent, so that it was necessary to blend the tobacco with some other very mild type before using it for the manufacture of cigars. This filler was classed as a strong, very heavy type, although the total nicotine content was only 2.20 per cent, while many of our domestic filler types contain as much as 5 per cent of nicotine. The amount of this nicotine soluble in petroleum ether was determined. To a portion of the tobacco about 2 per cent of citric acid was added in aqueous solution by spraying, after which the sample was cased down for two days to allow the citric acid to diffuse through the leaf as far as possible. The nicotine in this sample before and after extraction with petroleum ether was then determined. For comparison, a sample of imported Cuban filler known as "Santa Clara," which is a very mild type and which showed only a slight sharpness in the smoke, was also tested as to the amount of nicotine soluble in petroleum ether.

The results of these tests are shown in the following table:

TABLE II.—*Nicotine soluble in petroleum ether in domestic filler tobacco before and after the addition of citric acid.*

Nicotine content.	Domestic filler tobacco.	Domestic filler tobacco, with citric acid added.	Imported Cuban Santa Clara tobacco.
	Per cent.	*Per cent.*	*Per cent.*
Total nicotine	2.20	2.13	1.33
Nicotine insoluble in petroleum ether	0.76	1.66	0.79
"Free" nicotine	1.44	0.47	0.54

It will be observed that two-thirds of the total nicotine contained in the domestic filler tobacco is in the easily volatile form which exists either in the free state or loosely combined with weak acids and that the addition of citric acid renders the greater portion of this insoluble in petroleum ether. The fact that the nicotine is not made wholly insoluble by the addition of the acid is accounted for partly by reason of the slight solubility of the nicotine citrate in petroleum ether, but mainly because the solution of citric acid added had not diffused throughout the leaf tissue. Better results could be obtained by adding the citric acid solution before the fermentation process is completed, thereby affording a better opportunity for the even diffusion of the acid through the leaf. Even under these unfavorable conditions the soluble portion of the nicotine was reduced below that of the mild Santa Clara sample.

Samples of this tobacco to which the citric acid had been added were made into cigars which were tested by a number of persons, and the universal opinion has been that the sharpness or pungency of the smoke has been almost entirely removed by this treatment. Other similar acids, such as malic and tartaric acids, are also efficient in overcoming this property of the smoke, but oxalic acid does not give satisfactory results. The easily volatile fatty acids, such as acetic acid, form easily volatile salts with nicotine and hence do not produce any decided influence in this respect. It has already been stated, moreover, that these salts are soluble in petroleum ether.

Citric and malic, succinic, and finally acetic and butyric acids merely represent intermediate stages in the degradation by fermentative processes of the sugars to carbon dioxid and water. Citric and malic acids exist in the leaf prior to the fermentation, and whether the quantity of these is diminished in this process depends in any given case on whether the loss occasioned by partial transformation of these into succinic, butyric, and acetic acids is made good by the formation of further quantities by fermentation of the sugars. Acetic acid is formed during the fermentation at the expense of the citric

and malic acids, and hence it follows that prolonged fermentation can never entirely remove the pungency of tobacco smoke due to the easily volatile nicotine. In the presence of an excess of citric acid, however, the greater portion of the acetic acid would be expelled because of its easy volatility.

Citric acid is a normal and valuable constituent of tobacco, and its addition in moderate amounts could not therefore injure the quality of the tobacco in any way. There is every reason to believe that its addition during the fermentation process would prove highly beneficial to those types of cigar-filler tobacco which contain excessive quantities of nicotine not already in combination with citric or malic acids. This could probably be best applied by spraying the tobacco at the time of turning the bulks with an aqueous solution of such concentration as to add from 1 to 2 per cent of the acid.

COMPOSITION OF TOBACCO SMOKE.

Now that we have seen that organic acids like citric, malic, or tartaric acid are efficient agents in preventing the nicotine contained in the tobacco from imparting an undesirable sharpness to the smoke, the question naturally arises as to the manner in which these acids effect this result. There would seem to be three possible ways in which this effect might be produced: (1) The nicotine salts of these acids are so difficultly volatile that the nicotine is decomposed in situ by the heat from the burning end of the cigar; (2) these salts, on account of their slight volatility at lower temperatures, are condensed from the smoke before it enters the mouth of the smoker and thus constantly accumulate in the unburned portion of the cigar; and (3) the nicotine passes into the smoke and enters the mouth of the smoker in the form of the salt instead of in the free state, thus losing its pungency or biting qualities. Which of these alternatives affords the true explanation can best be answered by smoking the tobacco in a suitable apparatus and determining the amount of the nicotine contained in the smoke and that remaining in the unsmoked ends of the cigars.

A number of investigators have endeavored to study the composition of tobacco smoke, but the problem presents many difficulties in the matter of securing satisfactory analyses. Without attempting to enter into this subject fully, it may be said in brief that the smoke is, in the first place, mixed with large amounts of nitrogen and small quantities of oxygen derived from the air used in the combustion. In addition to these, the smoke proper contains, as difficultly condensible gases, small but appreciable quantities of carbon monoxid, hydrocyanic acid, and probably also hydrogen sulphid. These latter are three well-known poisonous gases, although the quantities contained in tobacco smoke are probably too small to be of any special signifi-

cance. Among the more easily condensible constituents may be mentioned nicotine and its decomposition products, especially pyridin, an ethereal oil of fragrant odor and a complex mixture of thick, tarry substances. Of course the smoke also contains large quantities of carbon dioxid and water vapor resulting from the combustion of the tobacco. The nicotine content of tobacco smoke has been extensively studied by Kissling,[a] whose principal conclusions may be briefly summarized as follows: Considerably less than half of the total quantity of nicotine is ordinarily destroyed in the smoking of a cigar, and greater or lesser quantities enter into the smoke, depending on what portion of the cigar remains unsmoked. In the case of a lot of cigars containing 3.75 per cent of nicotine, when two-thirds of the entire cigar were smoked about 28 per cent of the nicotine in the smoked part of the cigar was contained in the smoke; about 12 per cent had accumulated in the unburned portion of the cigar, and about 60 per cent was destroyed. In another experiment in which nearly seven-eighths of the entire cigar were smoked, the percentages were 52, 5.5, and 42.5, respectively. Unfortunately, in these tests the cigars were smoked by drawing through them a constant flow of air instead of by intermittent "puffs,"[b] as in the actual practice of smoking, so that the above values are not entirely applicable. Kissling considers that the physiological effects of tobacco smoke are produced almost wholly by nicotine and its immediate decomposition products of the pyridin class of compounds.

We have carried out several experiments along the lines of those conducted by Kissling to determine more particularly the effects produced by citric acid on the nicotine content of tobacco smoke. A portion of the sample of tobacco repeatedly referred to in this paper was sprayed with an aqueous solution of citric acid in the manner already described, and was then made into cigars. Another portion of the same sample without the addition of the acid was also made into cigars. A like number of each was smoked in a suitable apparatus, the smoke being drawn through a series of flasks containing sulphuric acid to absorb the nicotine. The wash waters containing the nicotine from the smoke were then distilled in a current of steam to remove any indifferent volatile matter, an excess of alkali added, and the mixture was then again distilled. The distillate containing the nicotine mixed with pyridin and a relatively large amount of ammonia was accurately neutralized with sulphuric acid and then evaporated to dryness. The nicotine and pyridin were then separated from the ammonia by extracting the residue with small volumes of absolute alcohol. The apparatus used for smoking the cigars was so

[a] Dingl. Polyt. Journal, 1882, p. 64.

[b] The word "puff" in this paper is used to cover both the inhalation and expulsion of the smoke.

constructed that the air could be drawn through the cigars either in an uninterrupted current or intermittently, and the rate of smoking was so regulated that about thirty minutes would be required for the complete combustion of a cigar. In one series of experiments approximately two-thirds of each cigar were smoked, while in a second series only one-half of each was consumed. The results obtained are recorded in Table III, but it is to be understood that the values shown are only approximate, since they are influenced by a multitude of factors which can not be rigidly controlled. In experiments 1 and 3 the cigars were smoked by intermittent "puffs," while in experiments 2 and 4 they were smoked by a constant current of air. In every case the results given in the columns designated by "A" refer to cigars made of tobacco to which citric acid had been added, while those under columns headed "B" refer to cigars from the natural leaf. All results are expressed in percentages and are the averages obtained from smoking a number of cigars. The cigars used contained 2.2 per cent of nicotine. The percentages of nicotine given in the table are all calculated to the amount of nicotine in the portion of the cigar actually smoked, and not to that contained in the whole cigar. The values for nicotine include at least a portion of the pyridin formed by the partial decomposition of the nicotine, inasmuch as no method has been devised for the quantitative separation of these two substances.

TABLE III.—*Nicotine in the smoke of cigars made from tobacco to which citric acid had been added and those made from natural leaf.*

	Experiment 1.		Experiment 2.		Experiment 3.		Experiment 4.	
	A.	B.	A.	B.	A.	B.	A.	B.
Portion of total weight of cigars smoked	*Per ct.* 73	*Per ct.* 70	*Per ct.* 60	*Per ct.* 63	*Per ct.* 49	*Per ct.* 50	*Per ct.* 48	*Per ct.* 51
Nicotine of smoked tobacco found in smoke	25.5	34.5	27	31.5	....	....	22	26.3
Nicotine of smoked tobacco recovered from residual ends	14	8	54	42	29	18	48	40
Nicotine destroyed in process of smoking or expelled directly into the air from the burning end of the cigar	60.5	57.5	19	26.5	....	....	30	33.7

It will be seen that when about two-thirds of a cigar are smoked about 30 per cent of the nicotine of the smoked portion passes into the smoke, while from 10 to 20 per cent collects in the unsmoked portion, and the remainder is either destroyed or escapes into the air. The striking increase in the amount of nicotine which collects in the unsmoked portion of the cigar when it is smoked by means of a constant current of air instead of by intermittent "puffs" is due to the circumstance that in the first case practically all of the nicotine is drawn into, or through, the unburned portion of the cigar, while in the latter case a large portion of the nicotine escapes into the air

during the intervals between "puffs." The relative amount of nicotine which is to be found in the smoke depends chiefly on the relative length of the unsmoked portion of the cigar and on the rate at which the smoke is drawn through the cigar.

The point of chief interest, however, is the effect of the citric acid on the nicotine content of the smoke. It is apparent that in every case the quantity of nicotine in the smoke is reduced, while that which collects in the residual end of the cigar is correspondingly increased. This difference, nevertheless, is too small to account for the marked effect produced on the quality of the smoke. Apparently the only possible explanation of this pronounced effect on the sharpness of the smoke is that in the presence of the citric acid the nicotine enters the smoke in the form of a salt rather than in the free state, and thereby loses its pungency while still exerting the usual physiological effect.

CONCLUSIONS.

It has been shown in the preceding pages that there is no direct relation between the so-called "strength" of tobacco when used for smoking purposes and the total content of nicotine. However, a distinction must be drawn between two forms of nicotine contained in tobacco, one of which is easily volatile and readily soluble in petroleum ether while the other is volatile only at elevated temperatures and is almost insoluble in petroleum ether. The undesirable sharpness or pungency contained in the smoke from certain types of cigar-filler tobacco and which constitutes one of the two factors included in the term "strength" as applied to the smoke is due almost entirely to the volatile, easily soluble form of nicotine which acts as if it were in the free state. On the other hand, the true physiological effects of the smoke, as embodied in the term "fullness," are proportional to the total quantity of nicotine.

The pungent, harsh quality of the smoke is partially, but not entirely, removed by protracted resweating and aging of the tobacco, whereby the easily volatile nicotine is largely expelled. This undesirable property is entirely removed by extracting the tobacco with petroleum ether, which simply dissolves out the volatile nicotine. Finally, the addition of sufficient citric acid to the tobacco to combine with all of this easily volatile nicotine efficiently overcomes the sharpness or pungency of the smoke. It can best be added by spraying the tobacco with an aqueous solution when the fermenting bulks are being turned. The addition of the citric acid reduces somewhat the amount of nicotine in the smoke of the cigar, but not enough to account for the marked effect on the quality of the smoke. It is suggested, therefore, that probably the nicotine enters the smoke in the form of a salt rather than in the free state, thereby losing its pungency.

THE GRANVILLE TOBACCO WILT.

By ERWIN F. SMITH, *Pathologist in Charge of the Laboratory of Plant Pathology.*

HISTORY.

Attention was first called to the Granville tobacco wilt in September, 1903, by McKenney, then connected with this Department. He attributed it to a fungus (Fusarium) nearly related to those studied by the writer on cotton, melon, and cowpea. No proofs from inoculation were obtained by McKenney.

A few days after the appearance of McKenney's paper a bulletin was published by Stevens and Sackett, of the North Carolina Agricultural Experiment Station, describing this disease and attributing it to bacteria. Their diagnosis also depended solely on field observations and microscopic studies, but this part of the work was well done.

In 1905, as the result of personal examinations of infected plants, studies of the microorganism in pure cultures, and successful inoculations therefrom, the writer confirmed the findings of Stevens and Sackett as to the bacterial nature of this disease. Numerous successful infections of tobacco were obtained both by needle puncture from pure culture and by plantings in infected soil.

The organism was identified provisionally as closely related to *Bacterium solanacearum*, a species described by the writer in 1896 as the cause of a widespread and destructive brown rot of the potato, tomato, and eggplant. This conclusion was based on the similar behavior of the tobacco bacterium and of undoubted *Bacterium solanacearum* (derived from tomato and potato) in a variety of culture media. The shade of doubt remaining in my mind at that time was due to the fact that many cross-inoculations (potato to tobacco and tobacco to tomato), while showing multiplication of bacteria in the inoculated tissues and some other signs of disease (brown stain in the bundles, and on tomato stems the development of incipient aerial roots), did not contract the wilt.

THE CONTINUED PREVALENCE OF THE DISEASE.

Both in North Carolina and in Florida this wilt of tobacco has continued with increasing severity, the losses in 1908 being greater than those of any previous year. In North Carolina quite a number of

planters have lost whole fields and others considerable parts of fields. Still others have harvested their tobacco green to save some part of it. The entire loss in 1908 in North Carolina is not known, but is estimated at upward of $100,000.

In Florida the disease has also made great inroads in several places, causing serious losses for three or four years. In 1908, one man lost 20 acres of tobacco under shade by reason of it. The same year a company lost nearly every plant on 12 acres of home-grown Sumatra under shade and also a considerable part of 95 acres of imported Sumatra, also grown under cover (cloth). On many of these fields tobacco has followed tobacco for a long series of years (eighteen years in one field).

The worst feature of this disease is the fact that fields once infected remain infected indefinitely, or at least for many years, and are also useless for growing any other plant of this family, e.g., potatoes, tomatoes, eggplants, or peppers. The disease is therefore a very serious one. If it continues at its present rate of progress, tobacco growing in the infected districts will become impossible within a few years, and if it should extend to all the tobacco-growing sections of the United States this industry would be destroyed. It is therefore of the utmost importance to keep it out of sections which are still free from it. To this end correct information respecting its nature should be disseminated as widely as possible. An ounce of prevention is worth tons of cure—and, moreover, *a cure* is not in sight. Something may be done, however, by good field hygiene to restrict its progress.

BACTERIAL ORIGIN OF THE DISEASE.

The writer no longer has any doubt as to the bacterial origin of this disease. On two or three occasions he has found Fusarium on tobacco stems affected by this disease, but not commonly, nor ever exclusively. Generally there were also a great many bacteria present in the stems occupied by the fungus. Once I have observed Fusarium to be a secondary infection—in one plant out of many inoculated with the bacterium some years ago.

Almost all of the diseased tobacco plants examined by me from North Carolina and from Florida, a hundred or more, in several different years, were attacked by bacteria to the exclusion of fungi. Fusarium certainly was not present. Nothing here said, however, need be construed as a denial of the occurrence in this country of a Fusarium disease of tobacco, since it is very reasonable to suppose the existence of such a disease. There are many such diseases, as the writer was the first to point out. One occurs on the tomato and another on the potato. Why not one on tobacco? The evidence necessary to establish such a contention, however, is yet to be procured. Meanwhile we may consider the Granville wilt as solely bacterial in its origin.

NEW EXPERIMENTS.

Experiments by the writer in the summer of 1908 have demonstrated that the Carolina tobacco disease is readily communicated to tomatoes through the root system. These infections were obtained by transplanting healthy tomatoes into a bed of good hothouse soil in which tobacco plants affected by the Granville wilt had been buried recently. The stems of these tobacco plants, which were obtained from North Carolina, were swarming with the bacteria peculiar to this disease. The tomato plants were infected through *broken roots*, the plants being of considerable size when set into the infected bed.

The experiment was begun at the end of July, and up to this date (August 18) nineteen tomato plants have contracted the disease. This disease is typical tomato wilt, the vascular bundles of stems and mid-ribs being browned and their vessels filled with the grayish white bacterial slime peculiar to the genuine tomato disease. Dissections showed the brown stain and the bacteria in the bundles to be more abundant as one passed from the top of the plant toward the roots, and always one or more broken roots were found *diseased to the very end*, i. e., browned and occupied by the bacteria. Most of the roots, however, as well as all of the underground stem and all of the parts above ground, were free from external appearance of disease other than the wilt, i. e., from wounds, spots, or stains. The wilting was sudden, i. e., not preceded by any yellowing of the foliage. Numerous incipient roots developed on the stems. No other tomato plants in the houses or on the grounds (several hundred) showed any signs of this disease.

The Jimson weed (*Datura stramonium*) planted in this bed also contracted this disease through the root system.

Moreover, with bacterial slime taken from the interior of four of these wilting tomato plants (upper part of the stem) I have caused the Granville tobacco wilt inside of two weeks on four large healthy tobacco plants, the bacteria being introduced into leaves and stems by means of needle pricks, and also by pulling off leaves and rubbing the scars with the crushed tomato stems. The signs of this tobacco disease so obtained were in every way characteristic—wilt of foliage, darkening of the veins of the leaves, longitudinal dark stripes on the stem originating from internal staining, brown stain of the vascular bundles of the stem and leaves, and vessels gorged with the characteristic bacteria. Some of the uninoculated leaves also dried out irregularly, and the apical leaves on the inoculated side of the stem became dwarfed and distorted. The inoculations were made in another hothouse (where no other Solanaceae were grown), the checks remained healthy, and when the wilting plants were cut for examination the root system in three of the four plants was still free from disease, the inoculations having been made at the top of the plants. Moreover, in all cases (four places on each plant) the disease began in the pricked and rubbed areas.

SPECIFIC GERM INVOLVED.

The cultural characters of the tobacco organism are the same as those of *Bacterium solanacearum* derived from tomato or potato, and now that good cross-infections have been obtained no doubt remains that the Granville wilt of tobacco and the brown-rot of potato, tomato, and eggplant are one and the same disease, i. e., due to the same organism, all of these plants belonging to the nightshade family and being rather close relatives. The Florida tobacco wilt at Quincy and Hinson appears to be the same thing. I examined diseased plants from Florida some years ago and again this year.

The writer formerly stated (1896) that he did not succeed in cross-inoculating *Bacterium solanacearum* into tobacco and peppers, and at that time he believed tobacco to be exempt, but not many experiments were made, and we may assume either that the cultures used had lost their virulence or that the particular plants selected were too old or growing too slowly, or for some other reason were unusually resistant. The writer now believes that *Bacterium solanacearum* does frequently lose its virulence by continued culture; that, in general, old and slow-growing plants are difficult to infect; and that some individuals and some varieties are more resistant than others. This, I believe, sufficiently explains the former failures. We may conclude, therefore, in searching for remedies that we have one disease to deal with and not several.

METHOD OF ENTRANCE OF THE BACTERIUM.

If stomatal infections occur, which is not unlikely, especially in wet weather, they have not yet been demonstrated. So far as we know, this organism enters the plant only through wounds. Van Breda de Haan found the root system especially subject. Stevens and Sackett state that the infection is first in the root. A large number of infections undoubtedly take place under ground, the organism present in the soil entering the plant through wounds made in transplanting or cultivating, or by small animals infesting the soil. Roots broken in transplanting and leaves pulled or pinched off at that time are responsible for many infections, and it would seem that by care the number of such wounds inviting infection might be greatly reduced.

It has been observed in Sumatra, where occurs a destructive bacterial wilt some years ago identified by Hunger as due to *Bacterium solanacearum*, that the tobacco plants are peculiarly subject to it when grown on land infested with eelworms (nematodes) or with insects which attack the roots or base of the stems. Rainy weather is favorable to the progress of this disease, although the wilt may be detected first in dry weather. In this country it has been observed, especially by Earle on tomatoes in Alabama, that wet soil is peculiarly favorable to the spread of this disease. All observers agree that the root system

is peculiarly liable to attack. To a very considerable extent the destructive prevalence of this disease seems to hinge on the occurrence of root-infesting nematodes. They are common in the diseased tobacco soils of Florida and probably occur also in those of North Carolina.

REMEDIES AND PALLIATIVES.

(1) This organism is to be regarded as a very bad weed liable to be distributed in many ways. It is worse than ordinary weeds because it is invisible. On plantations free from the disease a rigid quarantine should be erected against plantations subject to the disease. Nothing should be received by the farmer from the latter—seeds, young plants, raw tobacco, cured tobacco, packing cases, wagons, tools, fertilizers, laborers, horses, cattle, etc., all should be excluded. Avoid also the manuring of fields with tobacco waste even when it is believed to originate from clean sources.

(2) Do not plant tobacco on lands subject to this disease. Rent healthy land at a distance if necessary. To plant infected land invites disaster. *It is not safe to do so even after several years.* Stevens and Sackett have recorded several cases where the disease returned after five to eight years rest of the soil, and one instance where it did not return after a rest of fifteen years.

(3) Do not cultivate any other similar plants on infected land. Tomatoes, potatoes, eggplants, peppers, and pepinos are all more or less subject to this disease, and their growth will help to continue the organisms in the soil. Grow plants of some entirely different family. Look out also for solanaceous weeds. It is not known whether these are actual harborers of the bacteria, but it is well to destroy them. In the hothouse the writer has found the plant called Stramonium, jimpson, or Jamestown weed quite subject to this disease. The disease is also readily inoculable into the black nightshade (*Solanum nigrum*).

(4) Search the affected tobacco fields carefully, especially toward the end of the season, in the hope of finding resistant plants from which seed may be saved for the breeding up of resistant sorts. There is some hope that this may be accomplished. The intelligent planter can serve himself in this matter as well as help to excite general interest in the subject. The end in view is worth the expenditure of much time and trouble.

(5) If it is impossible to avoid the use of infected lands, then certainly avoid planting the wettest spots, and underdrain such fields as speedily as possible.

(6) Select for the seed beds soil which is uncontaminated, and transplant to the field *early*, i. e., while the plants are quite small, *and with the greatest care to avoid breaking the roots.* Cultivate shallow with the same thought in mind. Under no circumstances use large plants

on such lands. The roots are certain to be broken more or less in transplanting and equally certain to become infected, with subsequent infection of the whole plant. Probably half the trouble on such lands, if they are free from nematodes, might be avoided by careful attention to this one particular. Under tents, sowing the seed in the place where the plant is to stand might also be given a trial.

(7) Wound as little as possible the base of the plants and the tops by pruning or pulling away leaves. Do not jerk off leaves when setting out. It is a good rule under ordinary circumstances to balance root and top by removing a portion of the leaves at planting time, *but not when this disease is present*, since infection is liable to occur in this way. The same end may be accomplished with less danger to the plants by using greater care in transplanting, and especially by transplanting when the plants are small. Top the plants in dry weather.

(8) Avoid fields known to be infected with root nematodes. They wound the roots and enable the bacteria to gain an entrance. Hunger demonstrated this on tomatoes in the Dutch East Indies. If such fields must be used, the nematodes may be reduced in number by rotation with winter grains (oats, rye, wheat) followed by velvet beans but not by cowpeas (except Iron), since ordinary cowpeas are much subject to root nematodes and will increase the number of them in the soil. Velvet beans are not subject to nematodes. The number of nematodes in the soil may also be reduced by a skillful use of trap crops, but an unskillful use of the same will increase their number. The object of a trap crop is to get as many nematodes as possible encysted in the roots, which are then pulled up and burned. Cowpeas may be used as a trap crop. They should be removed and burned as early as the fourth week, i. e., before the nematodes have escaped again into the soil in increased numbers. It would be best, however, to put this work into the hands of persons having some knowledge of biology, since trap-cropping for nematodes is still in the experimental stage.

(9) Remove and burn affected plants as soon as they are detected. They are swarming with innumerable millions of infectious particles[a] which plowed under or allowed to fall to the ground are washed into the earth and will serve to increase the soil infection. Such plants are also a source of danger to your own free fields and to those of your neighbors. There are enough neglected tobacco plants in Granville County to infect the whole United States if properly distributed.

(10) Under no circumstances throw tobacco refuse on your fields, or into your barnyard, or into streams or roadways. Such refuse is a good fertilizer, but it may also prove the carrier of this disease and the danger is too great. The organism may live in the dead stems for some time—just how long is not known. Do not take any risks. The

[a] A single tobacco plant may contain ten thousand million of these bacteria.

organism is not known to produce spores and is believed to be destroyed by a short exposure (ten minutes) to 52° C. (125° F.), but until it has been confirmed on a large scale in the field it is best to be cautious about using waste material from the curing house. Some portion of it containing these bacteria may not have been heated hot enough to destroy them.

(11) Strive to keep uninfected fields free from infection. To this end look out for the tobacco refuse; also for wash of rain water from infected lands (this to be turned aside by ditches and dikes). Be watchful also for other sources of infection, e. g., dirt or fragments of infected tobacco carried on tools, feet of horses and cattle, etc.

Tools may be disinfected (after removing the dirt) by a short exposure to live steam, boiling water, or the open flame (gasoline torch). Five minutes' exposure ought to be ample. They may also be disinfected by the use of germicides, e. g., 5 per cent carbolic acid (poison) or one-fifth per cent mercuric chlorid (poison). Carbolic acid or mercuric chlorid (corrosive sublimate) are better than formalin, since the latter is volatile and likely to be under the certified strength (40 per cent formaldehyde) in broken packages or old corked bottles. Mercuric chlorid tablets prepared for this purpose, so that weighing is not necessary, are on the market. Wooden pails and clean boiled water should be used. The germicidal action of mercuric chlorid is destroyed by contact with metal dishes. These substances should be kept out of reach of children.

(12) Avoid also the increasingly common southern practice of sowing fields with dirt from other fields, the idea being to inoculate the soil with nitrogen-fixing organisms. This method of inoculating soils is a bad practice under any circumstances, i. e., one well calculated to disseminate plant parasites and one particularly reprehensible in localities where this disease prevails or is liable to occur. Nematodes, injurious insects, parasitic fungi, club-root of cabbage and other crucifers, and plant-destroying bacteria, not to mention animal parasites, are all liable to be disseminated in this way. To let loose a whole menagerie for the sake of obtaining an ox or an ass is not a good policy. Obtain pure cultures for soil inoculations from the Department of Agriculture or the State agricultural experiment station.

(13) Those who grow Sumatra wrapper-leaf tobacco under tents erected at great expense, and whose annual crop is worth $1,000 or $1,500 per acre, can afford greater expenditures in combating this disease than the ordinary planter. Such persons should endeavor to free the soil of this organism by fire or by steam heat. They should also combat the nematodes. *Bacterium solanacearum* is quite sensitive to heat, and if the whole body of the soil could be warmed up to 125° F. for fifteen minutes this organism would be destroyed. If such attempts
fifteen minutes this organism would be destroyed. If such attempts
are made great care must be taken that the sterilized portions are not

reinfected by careless workmen from the parts not yet treated. Live steam under considerable pressure conveyed through parallel lines of buried gas pipes and let loose into the soil at short distances by suitable *small* openings is probably the best method of applying steam. It may be applied, however, as Shamel has recommended for seed beds, i. e., under large shallow metal pans, which are then moved to a fresh portion of the field, and so on until all is treated. A lettuce grower in Boston has invented a sort of drag-tooth device of gas pipe which is driven down into the soil and steam turned on for a half hour or more. This is then lifted and driven down in another place, and so on until the whole bed is covered. It effectually sterilizes the soil, but the labor is very considerable.

(14) Get your neighbors to unite with you in carrying out these measures.

RECAPITULATION.

The tobacco wilt is due to bacteria. They occur in the diseased plants in enormous numbers. They infest the soil and remain alive in it a long time. The plants are commonly infected through injuries due to nematodes (eelworms) which cause swellings on the roots, or through roots broken in setting out. Late transplanting from the seed bed is very disastrous when this microorganism is in the soil. Potatoes, tomatoes, eggplants, and other members of the nightshade family are also subject to this disease.

Sound plants depend on planting in uninfected land. To keep uninfected fields free and to reduce the amount of infectious material in diseased fields, remove and burn the diseased plants and practice the other hygienic measures here recommended.

Immediate remedial measures should look to reducing the number of nematodes in the soil; to greater care in transplanting, so that the plants, and more particularly the roots, shall not be wounded; and under tents, if the cost is not prohibitive, to destruction of the bacteria by steam heat.

Remote remedial measures should look to breeding up races of tobacco, which shall be resistant to this disease either directly or indirectly by being resistant to root nematodes.

B. P. I.—463.

THE FLORIDA VELVET BEAN AND ITS HISTORY.

By KATHERINE STEPHENS BORT, *Laboratory Aid, Forage Crop Investigations.*

HISTORY OF THE FLORIDA VELVET BEAN.

The most important leguminous forage crop grown in Florida is undoubtedly the velvet bean. In the past fifteen years it has rapidly grown in importance as its value has come to be more and more appreciated. In so far as one can rely on the memory of various residents in Florida, the velvet bean was known there at least as early as 1875, but no documentary evidence earlier than 1890 has been found. In connection with the study of the Florida velvet bean the interesting fact develops that the plant does not belong to any of the species to which it has been referred, but on the contrary is a distinct species not heretofore properly characterized or named. The detailed history of the plant as far as the documentary or published evidence is concerned is given below.

On September 8, 1890, Hon. J. M. Rusk, Secretary of Agriculture, writing to Mr. S. C. Carleton, Argo, Fla., in a letter preserved in the files of the United States National Herbarium, acknowledges the receipt of "a peculiar seed of a bean," and continues the letter as follows:

The plant is apparently a species of the genus Mucuna. The National Herbarium contains nothing exactly like it and it is probably of tropical origin. I shall be glad if you will send us some specimens of the vine, portions of the stem a foot or two long with some flowers, leaves, and fruit in position. We wish to prepare the specimens for permanent keeping in the herbarium. I mail you to-day a box in which the plant can be placed and sent free of postage.

No further correspondence has been found, but in the United States National Herbarium are several specimens sent in by Mr. Carleton under date of September 22, 1890, on one of which is the information "introduced with coffee seed," and on another "introduced from tropical America of West Indies." These specimens were mistakenly identified as *Mucuna pruriens* L. The plant is the Florida velvet bean, and the above is the first documentary record concerning it that has yet been found.

In Bulletin No. 35 of the Florida Agricultural Experiment Station, published in April, 1896, Mr. O. Clute writes as follows:

Early in 1895 my attention was called to a "pea" which was reported to grow luxuriantly in poor soil, to give a large amount of forage, to yield an unusual amount of peas, and to be eaten readily, both forage and peas, by all stock. The gentleman who reported this pea has no name for it. Afterwards the same plant was found in Lake City and in other places in Florida, grown as an ornamental on trellises for shading piazzas, under the name of velvet bean. * * * It began to bloom in August, producing long clusters or racemes of somewhat large purple flowers, which were quite ornamental. The bloom was followed by plump pods of rich, dark green, covered with a close down, like velvet, whence probably comes the name of "velvet bean." * * * I have not been able to learn the botanical name of the plant. Probably it was introduced as an ornamental climber. It may have come years ago from the Patent Office, or more recently from the Department of Agriculture. * * * Mr. A. P. Newheart, of Ocoee, Fla., of whom I obtained the seed planted at the station at Lake City, called the plant a pea. He writes as follows: "Your letter is at hand. At your request I will state that I know nothing of the origin of the pea, and can find no one among the old settlers that has the least knowledge where the pea came from. It has been planted here some twenty years, solely as coverings for trellises and unsightly places."

In December of the same year that Mr. Clute published his bulletin, Mr. Gerald McCarthy, in Bulletin No. 133 of the North Carolina Agricultural Experiment Station, has this note:

Banana or Velvet Pea.—*Dolichos multiflorus* (Plate I).—The banana pea is not a true cowpea, though closely related. Its botanical name is *Dolichos multiflorus*, and it is a native of the southern part of Florida, extending southward into the Tropics. This pea is much more tender as regards cold than the common cowpea, and this, with its extremely long season of growth, reduces very considerably its agricultural value for North Carolina and colder States. The seeds are large, roundish, granite color, and speckled like the common "speckled" pea. The growth of vine is enormous, far exceeding any other legume known to agriculture, reaching 20 to 30 feet.

The identification of the Florida velvet bean as *Dolichos multiflorus* Torr. (*Dioclea boykinii* Gray) is clearly erroneous. That plant is native in Florida and is very different from the velvet bean.

Since 1896 there have been frequent press notices of the velvet bean. Some of the more important, as throwing light on its history, are the following:

Seven years ago only two grove men here had planted the velvet bean: from these the acreage planted in orange groves gradually increased until last year there were about 25 orange groves planted to the velvet bean. The results were so favorable that fully 300 orange growers planted the bean for fertilizer alone this year.—*Florida Farmer and Fruit Grower (Jacksonville, Fla.). November 27, 1897, p. 757.*

Although notes on this plant have already appeared in the Queensland Agricultural Journal for August and October, 1897, I think that the following infor-

mation respecting its growth in this colony may be of interest to Queenslanders, as the previous notes were simply extracts from American journals, and the information they gave more applicable to American than to Queensland conditions.

In the first place, the plant has been wrongly named, as it is not *Dolichos multiflorus*, but is recognized by Mr. F. M. Bailey, to whom I submitted specimens, as *Mucuna pruriens*, var. *utilis*, a variety of the plant commonly known as "Cowhage" or "Cow-itch." The description already given of this plant is substantially correct, so I will simply refer my readers to the illustration herewith,[a] which has been drawn by the artist to the department from a plant grown[b] at the Redland Bay Experiment Farm.—*Albert H. Benson in Queensland Agricultural Journal, May, 1898, p. 370.*

Velvet Bean (*Mucuna utilis*).—Annual; climbing; stems sometimes 50 feet in length; leaflets 3, large; pods numerous, 2 to 3 inches long, each containing three or four large oval beans.

A newly introduced plant which has not been extensively tested, but which has been highly recommended by the experiment stations of Louisiana and Florida.—*United States Department of Agriculture, Division of Agrostology, Bulletin No. 15, "A Report Upon the Forage Plants and Forage Resources of the Gulf States," by S. M. Tracy. July 15, 1898.*

Florida Velvet Bean.—Under this name a leguminous plant has been prominently recommended in American journals as a forage plant and as admirably adapted for green crop manuring. Recently the beans have been offered for sale in this country. As frequent references have been made to Kew, it is desirable to place on record what is known of the plant and its capabilities. As to its identity, it was from the first conjectured that the seeds belonged to a plant very near the common purple-flowered Cowhage or Cow-itch plant of the Tropics, *Mucuna pruriens*. The difficulty, in the absence of adequate specimens, in identifying it with this was the fact that in the Cow-itch plant the pods are densely covered with stinging hairs of a brownish color. A plant so formidably armed, it was thought, could not safely be recommended for general cultivation. The name first given, *Dolichos multiflorus* (*Dioclea boykinii*), was clearly wrong. In these circumstances we are glad to find from the Queensland Agricultural Journal, volume ii, pages 370–371 (with a plate), that the plant has flowered and fruited in that colony, and that Mr. F. M. Bailey, F. L. S., the colonial botanist, has identified it as *Mucuna pruriens*, var. *utilis*. In this variety of the Cow-itch plant the pods are apparently devoid of stinging hairs. It is probably *M. utilis* of Wallich, described in Flora of British India (vol. ii. p. 187) as "cultivated variety" with velvety not hairy pods. This is figured in Wight's Icones (vol. i, t. 280). According to Watt's Dictionary of the Economic Products of India, "the young, tender pods are cooked and eaten as a vegetable." What may also prove to be the same plant, with jet black seeds, is cultivated as a rotation crop on sugar estates in Mauritius under the name of "Pois Mascate." The accounts given by interested parties in America respecting the agricultural value of the Florida velvet bean must be received with caution.—*Kew Garden Bulletin of Miscellaneous Information No. 140, August, 1898, p. 207.*

The Florida Velvet Bean.—As I am receiving so many letters of inquiry from your readers about the Florida velvet bean, and being unable to answer each one separately, I would like to reply through the columns of your valuable and widely read paper.

[a] There is a plate showing the velvet bean. [b] From American seed.

I have been asked so many times by people all over the country to give them the origin of this marvelous and most wonderful forage and fertilizing plant, and from what country it came. I will answer by saying that its presence here in Florida can be traced back twenty-five years or more, and it has until recently been known among the common people as the "Climber." From weight of evidence I unhesitatingly give Florida the credit of being its original home.

During the past year the writer introduced this little wonder in almost every civilized country on the globe, and a crop from the seed sent has been grown the present season; but from reports received it still remains a stranger to all. No one so far as heard from claims to know anything about it. The celebrated Kew Gardens, London, grew it the present season as a curiosity. Its vigorous growth and wealth of foliage and vine attracted wide and universal attention. Every State in the American Union is also putting it to the test. From a flood of letters received I learn that, from late planting and early frosts, the seed is not maturing in all sections of our country. But as a successful feed, forage, and fertilizer crop, it has nothing but praise from every quarter, and condemnation from none. Our Government at Washington, recognizing its great value to our country at large, bought a carload of seed of the writer last July for distribution to the several States of our Union.—*Capt. E. A. Wilson, Florida (no town mentioned), in Agricultural Epitomist (Indianapolis, Ind.), February, 1899, p. 4.*

From the year 1898, wherever the velvet bean is mentioned, it is spoken of as *Mucuna utilis*, and publications devoted entirely to it began to be published, notably the following:

Alabama Agricultural Experiment Station Bulletin No. 104, "The Velvet Bean," by J. F. Duggar. April, 1899.

United States Department of Agriculture, Division of Agrostology. Circular No. 14, "The Velvet Bean," by Jared G. Smith. May, 1899.

Florida Agricultural Experiment Station Bulletin No. 60, "Velvet Bean," by H. K. Miller. January, 1902.

Bailey's Cyclopedia of American Agriculture, volume 2, pages 656–658, "Velvet Bean," by H. H. Hume. 1907.

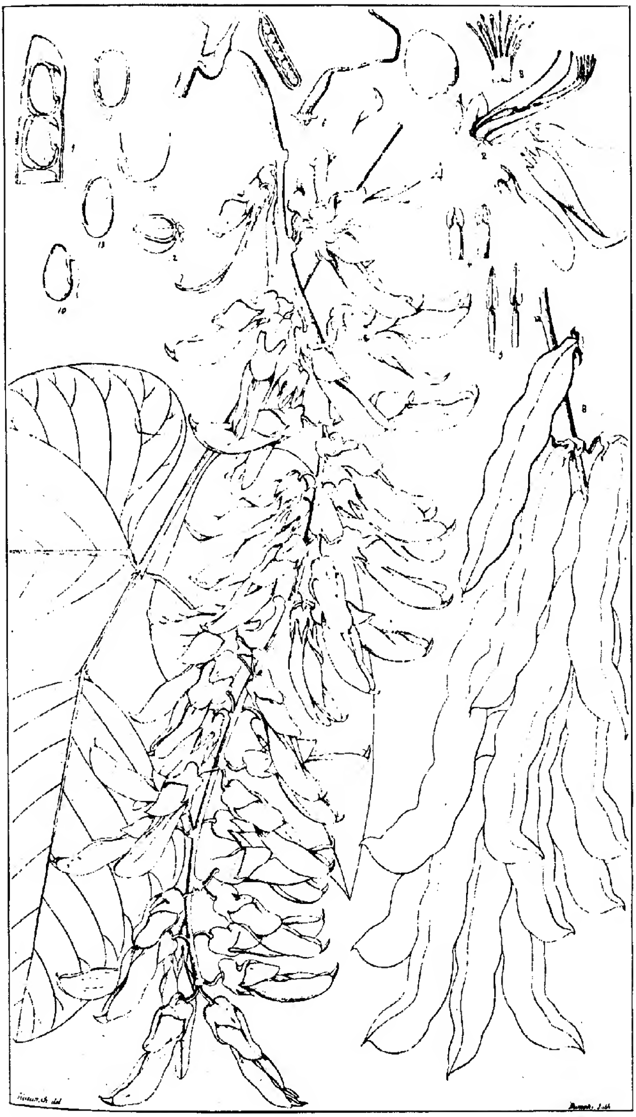
THE IDENTITY OF THE FLORIDA VELVET BEAN.

The original description of *Mucuna utilis* by Wallich[a] is as follows:

The principal difference of this species, if indeed a species, and *M. prurita* consists in the hairs of its legumes being appressed and almost silky, not erect, rigid, and stinging. In all other respects they sufficiently agree. The flowers in both are purple. The greater size of this is probably attributable to cultivation, in which state only it is known.

This brief description is accompanied by an excellent plate of the plant, natural size, which is herewith reproduced, reduced one-half. (See Pl. I.) The identity of this plant of Wallich's is decidedly obscure. It is extremely difficult to see how it can be a mere variety of *Mucuna prurita*, as has been held by some authors, and it certainly has

[a] Wight. Icones, t. 280. 1842.



WALLICH'S PLATE OF MUCUNA UTILIS, REDUCED SLIGHTLY MORE THAN ONE-HALF.

The description accompanying the original plate is as follows: "(1) Raceme, natural size; (2) a dissected flower; (3) stamens, showing the alternate long and round anthers; (4) round anthers; (5) long ones; (6) ovary; (7) the same opened; (8) cluster of pods; (9) portion of a legume opened; (10) a seed; (11) the same cut longitudinally; (12) transversely; (13) the cotyledons, testa removed; (14) embryo."

nothing to do with the West Indian *Mucuna pruriens*. As Hooker[a] long ago pointed out, the striking differences between the West Indian and the East Indian species are that the former has acuminate leaflets, whereas in *Mucuna prurita* they are obtuse or obtusish; *Mucuna pruriens* has a loose raceme, while *Mucuna prurita* has a dense raceme; *Mucuna pruriens* has the calyx lobes triangular and narrowly acuminate, whereas in *Mucuna prurita* they are rather broadly triangular and merely acute; *Mucuna pruriens* has a few inconspicuous stinging hairs on the calyx, whereas in *Mucuna prurita* they are much more numerous and are conspicuous on account of their rusty color. The seeds of the two species are also distinct. Those of *Mucuna pruriens* have a dark, brownish gray ground color with longitudinal markings of black. In all samples of *Mucuna prurita* examined the seeds are nearly black and unicolored. It may likewise be pointed out that the seeds of *Mucuna pruriens* are larger and not flattened on the sides, with the hilum only about one-half the length of the seed, while in *Mucuna prurita* the sides of the seeds are distinctly flattened and the hilum fully two-thirds as long as the seed.

In this connection the remarks of Voigt[b] are of interest. Under *Mucuna utilis* he says: "Certainly different from *M. prurita*, which has been cultivated in the garden here for many years, without its pods becoming less stinging." Voigt further identifies *M. utilis* with the black bean of Mauritius and Bourbon. This last-mentioned plant has been grown during the past season at Biloxi, Miss. Specimens of it agree exactly with the plate of *M. utilis*. It is also exceedingly probable that *Mucuna capitata* (Roxburgh) Wight and Arnott is the same thing, as the description agrees perfectly.

It is impossible to consider the Florida velvet bean the same as *Mucuna utilis*, from which it has several marked distinctions. The principal points of difference are as follows: *The size of the pod*, that of *Mucuna utilis* being 4 to 4½ inches long and ¾ inch wide and the Florida velvet bean usually under 3 inches long and not so wide; *the shape of the pod*, that of the Florida velvet bean being more cylindrical and blunt at the ends, less pronouncedly falcate, and not so decidedly ridged longitudinally; *the pubescence on the pod*, that of *Mucuna utilis* being thin, "appressed, and almost silky" hairy, while that on the Florida velvet bean is very dense, velvety, very soft, and weak; *the shape and size of the seed*, that of *Mucuna utilis* being large, long-oval, and flattened, whereas that of the Florida velvet bean is almost spherical and of smaller size; *the color of the seed*, which in the description of *Mucuna utilis* is not given, but from

[a] Hooker. Bot. Misc., vol. 2, p. 348. 1831.
[b] Hortus Suburbanus Calcuttensis, p. 235.

the figure the seed is not mottled or speckled, whereas the Florida velvet bean is. A comparison of figure 1 and Plates I, II, and III will illustrate the difference between the two plants.

FIG. 1.—A cluster of mature pods of the Florida velvet bean. Two-thirds natural size

The other described species belonging to the same group as the Florida velvet bean are *Mucuna cochinchinensis* Lour., which has white flowers and thick legumes, color of seeds not given; *Mucuna capitata* (Roxburgh) Wight and Arnott, with purple flowers and black shining seeds; *Mucuna nivea* (Roxburgh) Wight and Arnott, with white flowers and ash-colored seeds; *Mucuna lyoni* Merrill, with white flowers and ash-colored seeds, but quite distinct from *Mucuna nivea; Mucuna velutina* Hassk., with purple flowers and six different varieties as regards seeds, none of which are at all like the Florida velvet bean; *Mucuna bracteata* Baker, with gray leaves, broad, ovate, persistent bracts, and pods covered with gray, velvety tomentum when young; *Mucuna macrocarpa* Wallich, with woody stems and very large, half-woody pods, which are 1 to 1½ feet long and 8 to 12 seeded; and *Mucuna hirsuta* Wight and Arnott, with very hairy branches and densely silky leaves, especially beneath, and pods covered with stinging hairs. Most of the above species, and in addition three apparently undescribed species, were grown in 1908 at Biloxi, Miss. These species are all very much alike in habit, the most obvious differences being found in the calyx, in the character

LEAF, CLUSTER OF FLOWERS, AND CLUSTER OF IMMATURE PODS OF THE FLORIDA VELVET BEAN. ONE-THIRD NATURAL SIZE.

MATURE PODS AND SEEDS OF THE FLORIDA VELVET BEAN. NATURAL SIZE.

of the pubescence on the pods, and in the shape, color, and size of the seeds. The differences in the character of the pubescence of the pods are such as to make it practically certain that they are specific in value and not merely varietal.

In view of these facts the Florida velvet bean is herewith described as a new species.

Stizolobium[a] *deeringianum* n. sp. An annual, herbaceous, climbing vine sometimes 20 meters in length when growing on supports, and even on the ground attaining a length of from 2 to 6 meters, bearing long, pendent racemes of purple flowers which produce dark, velvety pods 5 or 6 centimeters long. Stems rather slender, terete, sparsely pubescent, with white, appressed hairs, especially on the ridges. Petioles equaling or exceeding the leaflets, pubescent like the stem, and continued for 2 to 4 centimeters beyond the lateral leaflets; stipules subulate, pubescent, about 1 centimeter long; stipels similar but smaller; petiolules about 5 millimeters long, stout, very pubescent. Leaflets rhomboid-ovate, the lateral ones oblique, membranaceous, acuminate-cuspidate, 5 to 15 centimeters long, about half as broad, sparsely pubescent above, especially on the veins, more densely pubescent beneath, the white hairs closely appressed. Inflorescence a raceme or thyrsus 15 to 30 centimeters long, pendent, bearing 5 to 30 flowers, usually about 12; rachis like the stem, but more pubescent; flowers borne singly or in twos or threes on short lateral branchlets. Bracts lanceolate-subulate, very pubescent, early fugacious. Calyx pubescent within and without with short, white, appressed hairs, 2 lipped, the upper lip broadly triangular, the lower lip 3 cleft, the lobes triangular-subulate, the middle one longest; stinging hairs absent. Corolla dark purple, 3 to 4 centimeters long; standard less than half the length of the keel, darker than the rest of the flower; wings slightly shorter than the keel, rather broad, oblanceolate-oblong, obtuse; keel straight to near the tip, where it curves sharply upward, the tip firm and acute; anthers of two sorts alternately long and short, the latter on much broader filaments; ovary linear, pubescent; style filiform, pubescent nearly to the tip; stigma small. Pods when mature 5 to 6 centimeters long, turgid, densely covered with a soft, nearly black, velvety pubescence without stinging hairs; valves with 1 or 2 or sometimes 3 obscure longitudinal ridges. Seeds 3 to 5 in each pod, subglobose, marbled and speckled with brown or black, and sometimes both, on ash-gray ground color (though pure gray and, it is said, pure black occur rarely), 1 to 1.5 centimeters in diameter. Hilum white, oblong-crateriform, less than one-half the length of the seed.

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[a] The genus Mucuna, as recognized by Bentham & Hooker and Engler & Prantl, clearly consists of two distinct genera, as pointed out by David Prain (Journal of the Asiatic Society of Bengal, vol. 66, new series, p. 404, 1897).

The genus Mucuna is first published in Adanson (Fam., vol. 2, p. 325, 1763) and the type species is *Mucuna urens*. The genus Stizolobium was first published by Patrick Browne, in 1756, in his history of Jamaica, and the type species is *Stizolobium pruriens*. The two genera are easily distinguished by the seed. In Stizolobium the hilum is linear, elevated, and oblong-crateriform, extending from one-fifth to nearly one-fourth the circumference of the seed. In Mucuna as restricted to include such species as *Mucuna urens*, the hilum is much elongated and band-like, extending nearly all the way around the seed. Furthermore, Mucuna is hypogeous in germination, while Stizolobium is not.

This description is based mainly on specimens in the United States National Herbarium collected by S. C. Carleton, Argo, Fla., in 1890.

Common name, Florida velvet bean. The original source of the species is unknown. At present it is cultivated extensively in Florida and to a less degree elsewhere.

The name *deeringianum* is given to this plant in honor of William Deering, of Cocoanut Grove, Fla.

B. P. I.—468.

THE IMPORTANCE OF BROAD BREEDING IN CORN.

By G. N. Collins, *Assistant Botanist.*

INTRODUCTION.

A study of the primitive types of corn and the history of the more productive varieties affords many indications that the improvement of our varieties is being checked by the injurious effects of inbreeding and that a further advance can best be secured by more fully satisfying the natural requirement of cross-fertilization. The conspicuous increase in yield that results from the crossing of distinct varieties and the rapid deterioration that follows self-pollination strongly support this view. Unfortunately the more recent changes in the methods of breeders have not been in the direction of better provision for cross-fertilization, but toward a still closer approach to self-pollination, the attempt being made to apply to corn theories and methods derived from plants naturally adapted for self-fertilization.

Until recently, the study of evolution and heredity has had little effect on the methods employed by breeders of domesticated plants and animals. Improved varieties were developed before Darwin's time in much the same way that they have been since. Whether the doctrines of Darwin or those of Lamarck, Naegeli, Weismann, or Cope should be accepted as giving correct interpretations has seemed to be a purely academic question from the standpoint of the practical breeder.

It is entirely different with the recently elaborated theory of De Vries. Converts to this new hypothesis have not been slow to claim that it has an important practical bearing, especially when taken in connection with the facts of Mendelism. Serious changes in the methods of breeding are being urged that are likely to have very injurious effects if they are generally applied to our varieties of Indian corn.

The definite mechanical character of these theories and the facility with which they appear to explain some of the facts of heredity render them very convincing. There is a tendency to forget their limitations and overlook the fact that whatever their value with

close-fertilized plants like wheat they are entirely inapplicable to a cross-fertilized plant like corn.

The popularization of the new theories has continued until they are now not only urged as a basis for scientific experiments in breeding, but are even recommended as a guide for the practical farmer. It is assumed that uniformity is a normal condition. New "elementary species" are supposed to originate by sudden changes and then to remain uniform, so that no further change is possible after a "pure strain" has been isolated, until new mutations occur. If these theories were correct, then it would be true, as De Vries maintains, that the breeder is wasting time in attempting to ameliorate varieties by the continued selection of minute variations after the elementary species have been isolated.

The hundreds of improved forms of domesticated plants which have been derived and maintained by continuous selection through long periods of time sufficiently refute the claim that selection is ineffective and should warn breeders from the danger of abandoning too soon a system which has yielded such brilliant results. As applied to corn the De Vriesian doctrine is particularly dangerous, since it would replace the already close selection by a method of still narrower breeding, the nearest approach to self-fertilization that is possible with a cross-pollinated plant.

Independent of these theories, many corn breeders have been aiming at uniformity, and such will doubtless welcome this apparent justification. It is perhaps fortunate for the progress of corn breeding that the wide promulgation of these theories has been delayed until the fallacy of the system of close breeding is beginning to be appreciated and the more thoughtful and observant of our corn breeders are viewing with distrust the system of close selection and are casting about for an alternative method.

DEVELOPMENT OF THE PRESENT METHODS OF CORN BREEDING.

Stated broadly, the object of breeding field corn is to produce varieties that will give the largest yield of grain under given conditions. The latitude allowed by this simple object gives the corn breeder an advantage over the breeder of more specialized crops—an advantage which has not been fully appreciated. The varieties of sweet corn fall more nearly in the class with vegetables, and the many special requirements, such as taste, appearance, and uniformity make their improvement a much more complicated and very different problem from that of the improvement of field corn. With field corn the development of varieties with special qualities will not become an important consideration until the possibilities of corn as a human food are much more fully appreciated than at present.

In the early stages of corn breeding it was thought sufficient to select the largest and best-filled ears for seed. With the idea that like produces like, this was obviously the way to increase the size of the ear. It was soon found that some of the plants that produced large ears had undesirable characteristics and selection was moved from the crib to the field.

The next stage was reached when it was realized that, though the ear was large and well filled and the plant had no objectionable features, some of the plants failed to reproduce their desirable characteristics in subsequent generations. The finest plants are sometimes due to particularly favorable locations in the field rather than to inherent superiority. This led to the study of the behavior of the progeny of particular ears before deciding whether they were worthy of being used as the foundation of new varieties, and the so-called "ear to row" method of selection was developed. These more laborious methods of breeding have all operated to limit the number of individuals tested and to restrict the crossing.

The increased yields which follow an intelligent application of this method of selection when applied to an unimproved stock have caused two important factors to be largely overlooked: (1) The number of plants from which careful selection can be made by any one person is reduced from thousands to hundreds with a correspondingly reduced chance of securing the individuals really superior as breeders; (2) these methods restrict the free crossing that is normal to the species, unless accompanied by the extremely laborious method of hand-pollination, which still further reduces opportunity of selection and renders the method inadequate, except where experiments are conducted on a very large scale, beyond the reach of the average farmer.

It has long been known that self-pollinated ears yield plants of greatly reduced vigor, and that a few generations of self-pollination usually result in sterility. Yet in spite of this obvious danger sign, nearly all of our corn breeders have continued to produce varieties with the narrowest possible foundation, often by using a single ear as the basis of the new variety and taking measures to prevent the bringing in of any new strains for fear of contamination.

Had corn breeding developed independently the danger from narrow breeding would doubtless have been more fully appreciated, but modern corn-breeding methods have been largely adapted from methods that have proved successful with other crops, such as wheat, oats, and barley, in which self-pollination is the rule. With self-fertilized species it is as safe to start a variety from a single plant as it is to start a variety of apples from a single bud. Furthermore, these autogamous strains tend to show great varietal uniformity, and the

degree of this uniformity is regarded as the measure of the purity of the strain. With corn, conditions are different. It is normally interbred and normally exhibits considerable diversity in conspicuous characteristics—diversities difficult to suppress even when the closest selection is practiced.

UNIFORMITY NOT ESSENTIAL IN CORN.

In the cultivation of many plants varietal uniformity is a prime requisite, and with plants where seed is not the part for which the crop is grown this uniformity may be secured by narrow inbreeding and narrow selection, without imminent danger of deterioration. With many plants a reduction in the quantity of seed or in its germinating power is of relatively small importance. Close breeding may be necessary and permissible in such crops as beets, cabbage, lettuce, or tobacco, where uniformity in vegetative characteristics is required. It may be profitable to produce uniform varieties of chickens, dogs, or ornamental plants, even though such varieties may be short lived. But the fancier's methods are not applicable to field crops. The corn grower receives a relatively small part of his profits in the form of prizes awarded on the score card method of "point ratings," yet, except for the seedsman, this is the only monetary advantage in producing corn with perfectly uniform ears. That a corn planter should occasionally drop four or five grains instead of three in a hill is about the only reason that can be given for insisting upon uniformity in shape and size of kernels, and an occasional white speck in the yellow corn meal is advanced as sufficient warrant for the careful elimination from yellow varieties of all ears with white cobs. The desire for uniformity does not always have even these excuses. It is even urged by some breeders that the tassels and silk must be uniform in color, that the ears must be uniform in shape, with a fixed number of grains to the inch. There is not even a fancied pecuniary advantage in this, but it is held that diversity in even these unessential characteristics stamps a variety as mongrel and therefore undesirable.

Even the universal insistence upon large ears may not always be advisable, for it has resulted in the development of plants bearing single ears instead of the two or more ears that are normal to the species. Where the season is short the limitation to a single ear is a decided advantage, but under other conditions a plant producing two or three ears of moderate size may yield a quantity of shelled corn that sufficiently exceeds that on a single large ear to more than offset the additional cost of harvesting.

CONFUSION REGARDING THE TERM UNIFORMITY.

A misunderstanding regarding the meaning of the term uniformity has done much to spread the practice of inbreeding and has

worked great injury to the cause of corn improvement. To the few successful breeders who have produced varieties of lasting value uniformity has not signified an identity of measurable characters, but is a kind of similarity of expression, so to speak, by which the breeder recognizes a family resemblance, much as we recognize the relatives of our intimate friends, although at a loss to indicate wherein the resemblance lies. Thus to an experienced breeder two ears of corn, with measurable characters that coincide as closely as possible, will immediately be recognized as belonging to different types. The ears and grains may be of the same size and shape, the color and indentation the same, yet to the practical breeder the two ears would appear to be lacking in uniformity. Conversely, ears which are obviously dissimilar in these particulars will promptly be recognized as belonging to the same strain.

The score card was an attempt to reduce this intimate and almost intuitive knowledge of the practical breeder to an exact science for wider application, but it has proved a lamentable failure—lamentable because it gave rise to the idea that the uniformity of score-card ratings was the kind of uniformity which successful breeders considered essential to valuable strains of corn, and because uniformity in score-card ratings can only be secured by rigid inbreeding.

CULTURAL TENDENCIES TOWARD INBREEDING.

The cultivation of corn is of very great antiquity in America, and the cultural operations to which it has been subjected from the earliest periods have differed radically from those applied to other crops. With primitive people the seed of other cereals is unavoidably mixed in planting, but corn is usually stored on the cob and the ears used for seed are carried into the fields at the time of planting, and the kernels shelled off as they are to be dropped into the ground. Thus the plants from the same parent ear grow up together, and with most primitive tribes, though the plantings may be considerable in the aggregate, the individual fields are in most cases so small that one or two ears will often suffice for the entire field. The opportunity for crossing is thus very slight. It would be natural for even the most primitive man to select for seed the largest ears or those that particularly caught his fancy, and the same type would be selected year after year. The seed ears also figure in many religious ceremonies, which no doubt tends to the establishment of definite standards of selection.

It is universally believed by the Indians of Central America that the varieties of corn in each locality are best adapted to that locality, and that other varieties brought in from other regions never yield so well. That this belief is well founded has been demonstrated by

the numerous experiments of European settlers in tropical America, who are prone to regard as superstition this native belief and to import improved varieties from more or less distant localities. The failure is usually so complete the first year that the experiment is abandoned. This abnormal behavior of corn under new conditions intensifies the close breeding, and the close breeding in turn operates against the interchange of varieties by making the adjustments to the particular environment more delicate. That these primitive systems of breeding have not been indiscriminate is shown by the great number of well-defined types that exist among the American aborigines.

Among a number of primitive tribes where the cultivation of corn has reached a high state of development, the injurious effect of this close breeding appears to have been recognized, since they have methods of guarding against it. Thus the Indians in the region of Quezaltenango, in western Guatemala, and the Hopi Indians of Arizona make a regular practice of placing seeds of more than one local variety in each hill, with the idea that larger yields can be obtained in this way.

The very general fact that the immediate effect of crossing two closely bred strains is to increase the vigor is well exemplified in corn. Although this increased vigor of first-generation hybrids is well recognized by many practical corn breeders, the value of the fact has been largely obscured by the idea that the hybrid must be considered as a new variety and that uniformity must be secured before the results could have general application. To attempt to establish uniformity by a new course of selective inbreeding is to sacrifice the vigor gained by crossing.

Attention has been so persistently centered on the production of new and uniform strains that the yield and vigor of the first generation of hybrid plants as compared with the parents is seldom reported. In all the cases that have come to our attention the yield of the hybrid has been in excess of the average of the parents. Five cases reported by Morrow and Gardner,[a] of the Illinois Agricultural Experiment Station, gave increases over the average of the parents running from 1.9 per cent to 28 per cent, with an average increase of 14 per cent. McClure,[b] of the same station, also reports on 12 different hybrids of sweet, pop, soft, and flint varieties; 10 showed an increase in the weight of the ear in the first generation over the average of the parents, and one of the exceptions is explained by the author as being due to unfavorable situation, the decrease in the

[a] Morrow, G. E., and Gardner, F. D. Bulletin 25, Illinois Agricultural Experiment Station, p. 179. 1893.

[b] McClure, G. W. Bulletin 21, Illinois Agricultural Experiment Station, p. 82. 1892.

other case being 4.6 per cent, while the average increase for the whole series of 12 crosses is 16 per cent, running as high as 52.8 per cent.

If similar increases had been secured by any change in cultural methods, experiments to determine the range of applicability of the new method would have been promptly inaugurated and the true value of the facts ascertained. Although the fact has long been established that significant increases can be secured by crossing, we are still without knowledge regarding the conditions necessary for this increase. It is to be expected that the increase will be greatest between strains that have been closely selected, but there is no direct evidence on this point. We should also lose no time in securing information regarding the amount of difference that should exist between the strains crossed to secure the maximum increase of vigor. There is a wide and almost untouched field in this direction that will require an enormous amount of experiment and observation before justice will have been accorded to this possibility.

The definite and well-known facts that self-fertilization of corn inevitably leads to sterility and that the yield can be increased by the crossing of varieties have not been sufficient to attract attention to the dangers of inbreeding and close selection. No middle course between the indiscriminate planting of the general run of seed and the rigid selection of a definite type seems to have been seriously considered. Had it been realized that diversity is as necessary to the life of the species as is chlorophyll to the life of the individual plant, it would have been evident that one might as well breed to eliminate the green color from the leaves as to suppress this normal variation. From a consideration of the habits of the plant the course suggested in undertaking the improvement of corn would be to seek the best methods for continuing to combine distinct strains, thus utilizing the increased vigor and productiveness resulting from their interbreeding.

While the crossing of our more or less inbred varieties may confidently be expected to result in increased vigor and fertility, it is hardly to be expected that the full amount of the increase in yield that follows such crossing can be maintained in future generations. The probability is that a part of the increased fertility of the hybrids will prove to be confined to the conjugate generation; that is, to the generation immediately following the crossing. In this generation male and female elements, representing the two parent varieties, are present in the nuclei of the plant, but have not completed the process of conjugation, with the result that a sort of protoplasmic tension exists, in some way associated with increased vegetative and reproductive activity.[a] There is good reason to believe that this is

[a] Cook, O. F., and Swingle, W. T. Evolution of Cellular Structures. Bulletin 81, Bureau of Plant Industry, U. S. Department of Agriculture. 1905.

the case in certain cotton hybrids, and if it should also prove to be an important factor in the increased yields of corn hybrids the results would warrant the production of hybrid seed in a breeding plot each year for field planting the following year. To secure hybrid seed it would only be necessary to plant two distinct varieties in alternate rows, detasseling one variety and using the seed from the detasseled variety for the next year's general planting. Seed from the variety that was not detasseled would not be mixed and selections could be made to supply the breeding plot for the two following years. By detasseling the other variety in the next year a stock of pure seed of this also could be grown. By this system of alternation pure stocks of seed of the two varieties could be maintained. There would be produced every year a stock of hybrid seed for the field planting of the next year and a stock of pure seed of one of the varieties for planting the seed plots of the two following years.

The same result could be approximated by planting in the same way and detasseling one of the varieties in one half of the field and the other variety in the other half of the field. By this method seed of both the varieties would be secured each year, but there would be considerable indiscriminate crossing.

The fact that corn is wind-pollinated makes the continual production of conjugate or first-generation hybrids on a commercial scale immensely more practicable with corn than with any other field crop.

In still another way the artificial crossing of two varieties may be expected to increase the yield. With such hybrids none of the seed is self-pollinated, while with the crop grown in the usual way the percentage of self-fertilized grain must be very considerable. In most of our varieties the natural proterandrous tendency of corn has been reduced, until under ordinary climatic conditions the pollen of nearly every plant is still being shed when the silks become receptive. Unless the wind is blowing when the pollen is shed a large amount of self-pollination is inevitable. It is to be expected, therefore, that any method of treatment that would eliminate or reduce this self-pollination would result in an increase of the vigor and yield of the resulting corn plants, even without hybridization. The use of detasseled plants for the production of seed may thus be found worth while, quite apart from the question whether detasseled plants themselves yield more than those that are not detasseled.

Whatever may be the true explanation of the increased fertility of hybrid corn plants, the fact remains that larger yields of corn can be secured in this way. The study of the methods by which these important factors can be made most effective should at least receive a place by the side of the study of elementary species and the quest of uniformity.

THE ELIMINATION OF "BARREN STALKS."

Another factor which has worked toward the inbreeding and consequent deterioration of highly bred varieties of corn is the removal of the so-called "barren stalks." The elimination of nonproductive plants is undoubtedly desirable, but the removal of barren stalks as usually practiced is not a step in this direction. A truly barren stalk is one that fails to produce seed. So far as the seed is concerned, therefore, this elimination is automatic and inevitable, but it has been urged that the barren stalks must be removed before they produce pollen, on the theory that pollen from barren stalks is likely to cause deterioration in the progeny of neighboring plants. Where this practice is followed it results only in the detasseling of all proterandrous plants, for, as pointed out by Soule and Vanatter,[a] it is impossible to distinguish the truly barren plants at the time of tasseling. With many varieties, especially those which have not been subjected to rigid selection, some of the plants which eventually prove to be the most prolific show only small rudiments of ears at the time of tasseling. The continued removal of such plants results not in the elimination of barren stalks, but in the elimination of the plants which possess a valuable adaptation to avoid self-pollination. This weeding out of the more proterandrous individuals has been continued with some varieties until the majority of the plants produce staminate and pistillate flowers at the same time. When these varieties flower in comparatively still weather, there must be a large proportion of self-pollinated seed and a consequent weakening of the variety. This persistent tendency to proterandry can be thought of as a natural reaction of the species against the danger of extinction from inbreeding. Even the true barren stalks might represent a tendency on the part of the plant to become diœcious. In localities with very short seasons it may be well to discriminate against the tendency in the plant to put out ears too long after the tassel has matured, but elsewhere the avoidance of self-pollination is more important.

CONTINUOUS IMPROVEMENT THROUGH SELECTION.

The fact that narrow breeding in corn results in a reduction of vigor has remained unappreciated largely because narrow breeding is always accompanied by selection for yield and vigor. The two processes are opposed, so that movement in either direction is masked and counteracted. Varieties thus produced are delicately adapted to the exact conditions under which they have been selected, and often show marked deterioration when placed under new conditions. The very delicacy of the adjustment helps to insure the much desired

[a] Bulletin 165, Virginia Agricultural Experiment Station.

uniformity, for with any change of characters the debility of the stock becomes more manifest and the elimination of the variant individuals is certain. Increased yields are obtained by making the yield of the individual plants more uniform, even when the full possibilities of production are not approached. The best plants of a highly bred variety are not conspicuously more prolific than the best individuals in fields from unselected seed.[a]

This failure of varieties to continue to improve in vigor and fertility under continuous selection gives apparent support to the idea of De Vries that the initial selection of "pure strains" is the only progress that can be expected. It has already been seen that attempts to secure increased vigor by close selection are impeded by the weakening effects of inbreeding. When selection is not hampered in this way, but is directed to characters not dependent on vigor and fertility, and consequently not affected by inbreeding, continuous progress may be made. Thus in the selections made by Hopkins for high and low protein content, rapid and continuous progress was made and an extreme was reached far in excess of anything observed in the original sample. The last reports show that the plants were no more uniform with respect to these characters than at the beginning of the experiment.[b]

Though necessarily impeded by inbreeding, important advances in yield have been made by means of close selection, but the value of these improvements should not be allowed to obscure the fact that the full possibilities of production are not reached until the increment of vigor obtained by crossing has been added. Even if the yields obtainable by crossing were not larger than those to be secured by persistent close selection, it is easier to permit crossing than it is to provide the very careful and skillful selection required to maintain high yields without crossing. To use crossing as a means of sustaining fertility, instead of relying upon selection alone, would also keep our stocks in more normal physiological condition, more resistant to disease, and less liable to injury by adverse conditions.

SUMMARY.

The development of the present methods of corn breeding has resulted in greatly limiting the number of individuals that serve as a foundation for improved strains. The danger of this course, as

[a] It has recently been pointed out by Mr. O. F. Cook that the apparent advantage of selection is greatest in degenerating stocks. See Bulletin 146, Bureau of Plant Industry, U. S. Department of Agriculture, "The Superiority of Line Breeding Over Narrow Breeding."

[b] Smith, L. H. Ten Generations of Corn Breeding. Bulletin 128, Illinois Agricultural Experiment Station. 1908.

shown by the sterility of self-pollinated plants, has been unheeded, largely because theories and methods have been carried over to corn from other crops which are normally self-pollinated or where a high degree of uniformity is essential.

Great uniformity is of little or no economic value in corn varieties, and since it can be acquired only through close breeding it is actually undesirable to the grower. The natural requirements of cross-pollination make the problem of corn improvement entirely different from that of most of our cultivated plants.

Selection for increased yield with the maximum instead of the minimum of cross-breeding seems never to have been tried as a scientific experiment. On the other hand, the farmers of our corn-growing regions have practiced a system of broad breeding by choosing many ears from widely scattered plants in large fields and mixing the shelled corn before planting. Much of the basic improvement of our corn varieties may be ascribed to this system of increasing and maintaining vigor and fertility.

An effort to reduce the intimate intuitive knowledge of the successful breeder to measurable characters has led to the development of the score card. Instead of accomplishing the desired result, the score card has operated to intensify the closeness of selection, since uniformity in formal characters can be secured only by close breeding.

Although the methods that obtain among the primitive tribes of corn-growing Indians indicate that corn has been subjected to narrow breeding from remote times, the more intensive form of narrow breeding has been practiced for little more than a decade, yet the debilitating effects of this method are becoming apparent.

That corn is benefited by additional crossing, even when grown by primitive methods, is indicated by the custom which some tribes have of regularly mixing distinct strains to increase the yield.

It is abundantly demonstrated that the crossing of distinct varieties gives increased yields.[a] With the idea that only uniform varieties could be of value the practical importance of this fact has been overlooked and the gain has been limited by subsequent inbreeding of the

[a] After this report was submitted in January, 1909, an article appeared by Dr. E. M. East, of the Connecticut Agricultural Experiment Station (see American Naturalist for March, 1909), describing additional instances of increased yields of corn hybrids. Thirty different crosses between varieties were grown in comparison with the parent varieties, with the result that "In every case an increase in vigor over the parents was shown by the crosses." In the four cases in which the yields were measured the product of the hybrid exceeded that of either parent, the increase of the hybrids over the parents averaging 77 per cent. Doctor East also considers the practicability of producing hybrid seed for commercial plantings and outlines a method practically identical with that suggested here.

hybrids. Should the increased yield of hybrid plants prove to be greatest in the first generation or should the complete elimination of self-fertilization prove an important factor, it is quite practicable to maintain a continuous supply of hybrid or cross-pollinated seed.

A study of the habits of the plant from the standpoint of cross-fertilization makes apparent the nature of the so-called "barren stalks," which may be thought of as an adaptation to avoid self-pollination. The elimination of these proterandrous plants results in increasing the percentage of self-pollinated plants and is a practice of doubtful value.

The ill effects of inbreeding and selection for increased yield and vigor have tended to neutralize each other, and the consequent lack of continued improvement has lent color to the idea that continuous selection is ineffective. With characters that are not affected by decreased vigor continuous advance has been made by selection.

THE PRESENT STATUS OF THE CHESTNUT BARK DISEASE.

By HAVEN METCALF, *Pathologist in Charge*, and J. FRANKLIN COLLINS, *Special Agent, Investigations in Forest Pathology*.

HISTORY OF THE CHESTNUT BARK DISEASE.

In 1904 Mr. H. W. Merkel, of the New York Zoological Park, observed a disease which was destroying large numbers of chestnut trees in the city of New York. This disease is what is now known as the chestnut bark disease. Even at that time it is certain that it had spread over Nassau County and Greater New York, and had found lodgment in the adjacent counties of Connecticut and New Jersey. No earlier observation than this is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904. Conspicuous as it is, it is strange that the fungus causing this disease was not observed or collected by any mycologist until May, 1905, when specimens were received from New Jersey by Mrs. F. W. Patterson, the Mycologist of the Bureau of Plant Industry. In the same year Dr. W. A. Murrill began his studies of the disease, publishing the results in the summer of 1906. By August, 1907, specimens received by this Bureau showed that the disease had reached at least as far south as Trenton, N. J., and as far north as Poughkeepsie, N. Y., and was spread generally over Westchester and Nassau counties, N. Y., Bergen County, N. J., and Fairfield County, Conn.

PRESENT DISTRIBUTION.

The present distribution of the chestnut bark disease is shown on the accompanying map (fig. 2). By this it will be seen that infection is now complete in the general vicinity of the city of New York. Outside of this area the disease already occurs at scattering points in a number of States. In every case its occurrence has been definitely authenticated by specimens which have been examined micro-

scopically. Reports have been received indicating that the disease is found at many other places, but not being substantiated by specimens these localities have not been shown on the accompanying map. It is only fair to state, however, that such reports have been received from points as remote as Cape Cod, Wellesley, and Pittsfield, Mass.; Rochester and Shelter Island, N. Y., and Akron, Ohio.

The bark disease is entirely different from a disease which during the past twenty years has caused the death of many chestnut trees on the Atlantic slope, particularly south of the Potomac River. The latter disease, which is now being studied by the Department of Agriculture, is associated with insects, is much slower in action than the bark disease, and produces a stag-headed condition of the tree. It can be quite confidently stated that the bark disease does not yet occur south of Virginia and at only a few points in that State.

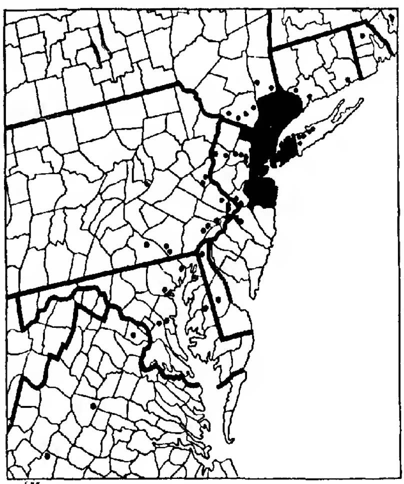

FIG. 2. Map of the eastern portion of the United States, showing the distribution of the chestnut bark disease. The heavily shaded part shows the counties wherein infection is already complete. The round dots show other points where the disease is positively known to occur.

Investigations are in progress to determine the origin of the bark disease in America and the details regarding its spread. The theory advanced in a previous publication of this Bureau,[a] that the Japanese chestnuts were the original source of infection, has been strengthened by many facts. It yet lacks much of demonstration, however, and is still advanced only tentatively.

While the disease has spread principally from the vicinity of New York there is much to indicate that it occurred at other points at an early date. Chester's Cytospora on a Japanese chestnut, noted at Newark, Del., in 1902, may have been the bark disease. Observations by the junior writer indicate that this disease may have been present in an orchard in Bedford County, Va., as early

[a] Bureau of Plant Industry, U. S. Department of Agriculture, Bulletin 121, Part VI. 1908.

as 1903, and that in Lancaster County, Pa., it probably was present as early as 1905. All other points shown on the map outside of the area of general infection appear to have been infected only within one or two years.

The bark disease appears practically to exterminate the trees in any locality which it infests. A survey of Forest Park, Brooklyn, showed "that 16,695 chestnut trees were killed in the 350 acres of woodland in this park alone. Of this number about 9,000 were between 8 and 12 inches in diameter, and the remaining 7,000 or more were of larger size."

In a recent publication Dr. W. A. Murrill estimates the financial loss from this disease "in and about New York City" at "between five and ten million dollars." The aggregate loss throughout the whole area of country affected must be much greater.

The bark disease occurs on both chestnut and chinquapin, regardless of age, origin, or condition. It does not occur on any other tree so far as known. All reports of its occurrence on the chestnut oak (*Quercus prinus*) have proved to be unfounded. It is not yet known whether the goldenleaf chinquapin of the Pacific coast (*Castanopsis chrysophylla*) is subject to this disease.

According to Sudworth, the range of the native chestnut is "from southern Maine to northwestern Vermont (Winooski River), southern Ontario, and southern shores of Lake Ontario to southeastern Michigan; southward to Delaware and southeastern Indiana, and on the Allegheny Mountains to central Kentucky and Tennessee, central Alabama, and Mississippi." The range of the chinquapin is "from southern Pennsylvania (Adams, York, Franklin, and Cumberland counties) to northern Florida and eastern Texas (Neches River)." The bark disease may, therefore, be expected to occur at any point within these limits, as well as in any other localities where the chestnut is grown as an ornamental or orchard tree.

CAUSE AND SYMPTOMS.

The disease is caused by the fungus *Diaporthe parasitica* Murrill (also known as *Valsonectria parasitica* (Murrill) Rehm). The spores of this fungus, brought by some means from a previously diseased tree, enter the bark through wounds; possibly also in other ways. The leaves and green twigs are not directly affected. From the point of infection the fungus grows in all directions through the inner bark until the growth meets on the opposite side of the trunk or limb, which in this way is girdled. The wood is but little affected. Limbs with smooth bark attacked by the fungus soon show dead, discolored, sunken patches of bark covered more or less thickly with the yellow, orange, or reddish-brown pustules of the fruiting fungus.

In damp weather or in damp situations the spores are extruded in the form of long irregular "horns," or strings, at first greenish to bright yellow in color, becoming darker with age. Plate IV, figure 3, shows a part of a branch of a diseased chestnut tree magnified 3½ diameters. In this illustration the typical appearance of the pustules in damp weather and the projection of the spores of the fungus in the form of "horns," or threads, are shown. These threads may be especially conspicuous near the edges of diseased areas. If the spot is on the trunk or a large limb with very thick bark there is no obvious change in the appearance of the bark itself, but the pustules of the fungus show in the cracks of the bark and, on account of the destruction of the layers beneath, the bark often sounds hollow when tapped. A patch usually grows fast enough to girdle the branch or trunk that it is on during the first summer.

The damage may not be immediately apparent, since the water supply from the roots continues to pass up through the comparatively uninjured wood to the leaves, but when in the following spring the new leaves are put out they are usually stunted and soon wither. The appearance of such trees is very characteristic. Plate IV, figure 1, shows large chestnut trees killed by the bark disease. In this illustration the trees to the left show the characteristic stunted foliage, which indicates that they were girdled during the previous year, while the tree on the right having no foliage was presumably girdled by the fungus at least two summers before the photograph reproduced was taken. Plate IV, figure 2, shows an orchard tree with recently girdled branches. Nothing else except an actual mechanical injury breaking off of trunk or limb—produces such an effect as is shown in these illustrations. The imperfectly developed leaves often persist on the dead branches throughout the summer.

The great damage which the disease has done thus becomes most apparent in the last week of May or the first week in June, giving rise to the false but common idea that the fungus does its work at this time of the year, when in reality the harm is done during the previous summer. If the first attack is on the trunk, of course the entire tree dies. If, on the other hand, the small branches are first involved, the tree may live for several years.

It is very easy for a person not familiar with fungi to confuse the parasite with various other fungi which occur commonly on the dead wood of chestnuts and other trees, such as species belonging to the genera Calocera, Cytospora, and Cytosporina. The superficial resemblance is sometimes very strong, but a microscopical examination instantly reveals the true nature of the organism in question. On account of this common confusion no dependable diagnosis of the bark disease can be made in a new locality without a microscopical examination of specimens by an expert.

FIG. 1.—LARGE CHESTNUT TREES KILLED BY THE BARK DISEASE.

FIG. 2.—AN ORCHARD TREE, SHOWING RECENTLY GIRDLED BRANCHES.

FIG. 3.—PART OF A DISEASED BRANCH OF A CHESTNUT TREE, SHOWING TYPICAL PUSTULES AND FORM OF SPORE DISCHARGE IN DAMP WEATHER.

(Magnified 3 diameters.)

RESTRICTION OF SPREAD.

HOW THE FURTHER SPREAD OF THE BARK DISEASE MAY BE LIMITED.

BY THE INSPECTION OF DISEASED NURSERY STOCK.

It becomes more and more evident as this disease is studied that diseased nursery stock is the most important factor in its spread to distant points. In that part of the country where it is already well established in the native chestnuts its progress is rapid and sure, but there is no evidence at present that it is able to pass to remote districts, tens or hundreds of miles away, except on diseased nursery stock. Of course it is conceivable that the spores are carried by birds. Such distribution would, however, follow in general the great lines of bird migration north and south and hence would not be an important factor in the western spread, except locally. During the summer of 1908 nearly every chestnut nursery and orchard of importance in the Atlantic States north of North Carolina was visited, and very few were found free from the bark disease. Several cases were observed where the disease had obviously spread from the nursery to adjacent wild trees. This is the only way in which the disease is likely to spread beyond the Alleghenies.

It is therefore obvious that every State in which the chestnut or chinquapin grows should as speedily as possible pass a law putting the chestnut bark disease on the same footing as other pernicious diseases and insect pests, such as the San Jose scale, against which quarantine measures are taken. The Department of Agriculture will be glad to give detailed suggestions or advice regarding the framing of such laws. Inspectors who already have legal power to quarantine against this disease should now take special care that no shipment of chestnut stock escapes their rigid inspection.

A campaign of education should also be undertaken by pathologists and inspectors in every State in order to acquaint the public with the nature and appearance of the bark disease, so that it may be quickly recognized and stamped out in any particular locality in which it appears. The Department of Agriculture will cooperate in the following ways: Specimens from suspected trees sent in by any person will be promptly examined and the presence or absence of the disease reported. Typical specimens showing the disease (with the fungus previously killed by soaking in formalin to insure against any infection from this source) will be sent upon application to any inspector, forester, pathologist, or other State or experiment station officer, to any nurseryman or orchardist growing chestnuts, or to any botanist or teacher of botany. So far as the supply permits lantern slides and photographs will, upon application, be loaned for special lectures, exhibits, etc., to the officers of States, experiment

stations, or colleges. By these means the inspectors first, and then the general public, may become familiar with the appearance and work of the disease in localities that it has not yet reached, and when it does appear may be able to recognize it before it is too late to take efficient measures against it.

Although its present distribution is that shown by the map (fig. 1), the bark disease may be confidently looked for in any orchard or nursery in the United States that contains chestnut trees. All such places should therefore be rigidly inspected at the earliest possible date.

By the Prompt Destruction of Diseased Trees.

When the bark disease is first noticed in any locality, all the affected trees should be immediately cut down, unless, as in the case of orchard and some few ornamental trees, they are of sufficient individual value to warrant special treatment. Diseased trees if untreated are doomed to death in any case. If permitted to stand, every such tree becomes a center of infection, certain to spread the disease to all neighboring trees, and so long as it will soon die if left to itself the sooner it is cut down the better.

When cut, the brush should be immediately gathered and burned in order to destroy the fungus in the bark. Whenever the bark is removed from the trunk, as, for example, when the trees are to be used for poles, it should be immediately burned with the brush. Even when the tree is to be used for firewood an effort should be made to cut off at least all the diseased patches of bark on the trunk and large limbs when the tree is cut and to burn this bark along with the brush; otherwise the brush and the piled wood will continue to spread infection, since it has been found that the fungus continues alive on dead bark for at least six months after cutting.

Sprouts arising from the stumps of cut trees will be free from the disease for the first year at least, but must then be carefully inspected to be sure that no infection has persisted.

By the Treatment of Diseased Trees.

During the past two years the Office of Investigations in Forest Pathology has been conducting certain experiments and collecting information in regard to the best methods of treating diseased trees.

At present it is impossible definitely to record general beneficial results from any of the sprayings which have been undertaken or have been under observation. This may in part be due to the fact that it is yet too early to judge satisfactorily all the results and in part, perhaps, to the infrequency of sprayings.

Observations and experiments seem to bear out the statement that it is very improbable that any method of spraying can interfere with the growth of the fungus if it has once established itself in the inner bark, but it may be of considerable importance in preventing the development of spores which come from other trees or from other parts of the same tree.

It has already been demonstrated that the crotches of branches and enlarged bases of sprouts are very susceptible to infection because they are favorable places for the lodgment of water, dust, spores, etc. In a large majority of cases infections are definitely known to have originated at a point where the outer bark had been injured in some way, leaving the inner living bark exposed, or where the entire bark over a more or less limited area had been stripped from the tree or cracked and split away from the wood. Certain injuries which are known to have afforded entrance for the disease have been of such a nature that they might easily be overlooked, while others have been quite obvious, even to the careless observer. Among the latter may be mentioned broken limbs, split limbs, branches which have been carefully cut but not properly treated with tar or paint, bruises from hames, plows, and cultivators; also poor grafts and diseased grafting scions. Among the former may be included bruises from boot heels, climbing spurs, holes made by borers and other insects, knife and saw cuts, and frost cracks.

Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease to a greater or less extent is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (where the size of the branch permits) beyond the characteristic, often fan-shaped, discolored areas produced by the growing fungus in the inner bark. All small infected twigs or branches should be cut from the tree, the cut being made well back of the diseased area. A pruning knife with an incurved tip, a hollow gouge, or any other clean-cutting instrument will serve for cutting out diseased spots. So far as the exigencies of the case will permit, all borers' holes should be cut out. It has been repeatedly observed in the field that infection often starts where borers are at work, or even at the old holes made by them. The paint or tar may be applied by means of a good-sized brush, care being taken to cover every part of the cutting. Treatment should begin, or observations at least, at the base of the tree and the fact ascertained whether the disease has

already girdled the trunk. If such is the case it will be a waste of time to attempt any treatment; instead, cut the tree down at once. A rigid watch must be kept, especially during the growing season, for new infections or infections which were overlooked in the earlier examinations, and if any are observed they must be treated promptly, as above mentioned. Constant vigilance is necessary to keep the disease in check. It is suggested that examinations be made about June 1. July 15, and September 1. During a very rainy or foggy season, when conditions are particularly favorable for the growth of fungi, it may be advisable to inspect as often as once a month.

In regions in which the disease is so widespread that almost every tree is infected, as, for instance, within 25 miles of the city of New York, it is extremely doubtful whether any individual treatment will pay. Under such conditions immediate reinfection is almost sure to occur at one or more of the small unnoticed abrasions or injuries which are quite certain to exist on most trees. In a region, however, where only isolated cases have yet appeared it is quite possible to stamp out the disease, or at least to prevent its rapid spread, by promptly cutting out and carefully burning all diseased bark and limbs, thus destroying these new sources of infection. If a tree is too badly infected to be worth treating it should not be left standing, for it will then become a continual menace to all surrounding chestnuts.

The Office of Investigations in Forest Pathology asks the cooperation of all persons who have observed the disease or experimented with it in any way. If such people will send in an early report of the kind of treatment used, time of treatment, methods employed, and results obtained (even if adverse), it may be possible to arrive at an earlier and more definite conclusion in regard to the possibilities or impossibilities of control than would otherwise be the case.

CONCLUSIONS.

It is to be hoped that in the economy of nature some limiting factor will arise to check the spread of the bark disease before it has wrought the same destruction throughout the country that it already has in the vicinity of New York. But at present there is nothing in sight that promises even remotely to check its spread into new territory except the general adoption of the measures advocated in these pages. It can not be argued that because of its apparently recent origin and rapid spread it will soon disappear of itself. Such diseases as pear-blight and peach yellows have been in the country for more than a century and yet show no sign of abating except when actively combated by modern quarantine methods. Nor can any conclusions be drawn from the fact that chestnuts in the Southern

States have suffered from a disease during the past twenty years, since, as already stated, that is a totally different thing from the bark disease.

Where the bark disease is already firmly established and has attacked 50 per cent or more of the chestnut trees, as in the vicinity of the city of New York, it is probably too late to try to do anything, but where the disease is just appearing there is no reason to doubt that strict quarantine methods will apply as well to this as to any other disease, whether of plants or animals. The question to settle is simply which is more costly—to use the methods recommended or to lose the trees. The people concerned must decide.

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